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ITALY'S VOLUMETRIC, SCARCE AND SOCIAL-SCARCE WATER FOOTPRINT: A HYDRO ECONOMIC INPUT-OUTPUT ANALYSIS

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Abstract

This study estimates the pressure exerted by Italian consumption on domestic and foreign water resources, adopting the Water Embodied in Bilateral Trade (WEBT) and Multiregional Input Output (MRIO) approaches, and using the information of the most recent (year 2014) World Input-Output Database (WIOD). Disaggregated results are obtained at country/industry level, identifying geographical and sectoral hotspots. We compare the volumetric measure of the water footprint (WF) with its impact-based measure, the scarce water footprint (SWF), and propose the concept of scarce social water footprint (SoSWF) incorporating criteria of social goals fulfillment. We find that SWF represents 33.9% of volumetric WF, but the geographical breakdown reveals a relevant asymmetry between domestic and external water exploitation: while only 11.2% of domestic WF exploited scarce water resources, SWF for imports amounted to 54.9% of the water used to produce imported goods. The Italian external SWF is highly concentrated in manufacturing, agriculture and electricity, gas and water supply in China and India. About 43% of WF generated impacts on socially scarce water resources. The inclusion of social criteria in the assessment of WF deepens the asymmetries between domestic and external footprints (12.8% vs. 71.1% of WF).

Key words: Input-output, Water footprint, Water stress, Italy

JEL Classification: C67, Q25, Q50

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1 INTRODUCTION

The concept of water footprint (WF) was introduced by Hoekstra and Hunk (2002) based on the concept of virtual water proposed by Allan (1993). The water footprint of a nation is defined as the total volume of fresh water used to produce goods and services consumed by the population of a country. The virtual water trade corresponds to the water contained in the products exchanged among countries. The total water footprint of a country includes two components: the part of the footprint that falls inside the country (domestic water footprint) and the part that presses on water resources in other countries (external water footprint) (Van Oel et al., 2009).

Although the concept of WF refers to a consumption-based approach (external and domestic water necessary to satisfy the final consumption of a given country), some studies adopt a production-based concept to refer to all water used to produce goods and services for both domestic consumption and exports (Ali et al., 2018). In this study we refer to this production-based concept as "direct use of water", following Duarte et al. (2016), to make the concept of water footprint unambiguous.

Three sources of water are usually considered in estimating the WF: *blue* water, corresponding to ground and surface water withdrawn for human uses; *green* water which refers to precipitation stored as soil moisture and used by rainfed agriculture; and *grey* water, the amount of fresh water needed to dilute contaminants to restore a minimum standard of quality in water bodies (Hoekstra et al., 2011).

To calculate the WF are used both bottom-up (BU) and top-down (TD) approaches. The BU approach is based on process analysis, providing detailed descriptions of water requirements of individual production processes, without considering both inter-sectoral and inter-regional linkages in production activities (Feng et al.,2011). The TD approach uses information from input-output tables to trace the whole regional, national or global supply chains. This is done in two different ways: while the Water Embodied in Bilateral Trade (WEBT) method traces water use only within domestic supply chains (accounting for inter-industry linkages), the methods based on Multiregional Input-Output Analysis (MRIO) trace the whole global supply chain to account also for interregional exchanges of water through trade (Peters, 2008; Feng et al., 2011).

Feng et al. (2011) estimate the water footprint for 113 countries based on BU and TD methodologies (both WEBT and MRIO), illustrating their results for eight selected countries. They find that the domestic WF estimates are quite similar between WEBT and MRIO, while important differences emerge in the external WF, even more relevant in the analysis at the industry level.

Recent studies have been conducted calculating the water footprint at the national level using the MRIO approach. Duarte et al. (2016) quantify the water footprint and virtual water transfers for the year 2009 within the European Union, using the World Input-Output Database (WIOD). Arto et al. (2016) perform the calculation for all the countries included in the WIOD database, estimating for the case of Italy a water footprint of 149,800 Mm^3 of which 87,000 Mm^3 corresponding to imported goods and services; the per capita water footprint is estimated equal to 2,512 m^3/year. Stee-Olsen et al. (2012) carry out an assessment of global WF using a global MRIO model based on the GTAP 7 database for the year 2004. For Italy the net displacements of environmental pressures of blue water to the rest of the EU corresponds to 50 Mm^3, and the total per capita blue water footprint of Italy is estimated as 210 Mm3/year. These two studies do not provide estimates of water imported (exported pressures of Italian consumption) disaggregated by country and economic sectors of origin.

Italy ranks fifth among virtual water importing countries, being the second largest per capita water importer with a value of 1,680 m^3 per capita (Hoekstra and Mekonnen, 2012), only behind the Netherlands. Thus, an Italian consumer generates significant pressure on water resources in other countries of the world, both the countries from which Italy imports directly, as well as those that supply goods and services to these countries.

Ali et al. (2018) focuses on Italy's WF at the national level using input-output tables[4]. The analysis is carried out for the period 1995-2009 using the WIOD[5]. The study calculates the balance between exports and imports of virtual water associated with the WIOD countries with direct trade relations with Italy, finding that only for three countries (United Kingdom, Germany and Japan) the balance is positive, that is, Italy is a net exporter of virtual water; for the rest of the countries the balance is negative.

An important issue relates to the fact that WF analysis should account not only for the *volume* of water used but also address the environmental impacts generated by the exploitation of water resources. A strong criticism of the volumetric concept of WF is made by Wichelns (2017). Volumetric measures of WF are only able to give an assessment of water consumption per unit of output. However, it is not the same producing in or importing virtual water from regions facing water scarcity problems than in regions with water abundance, as discussed in several studies (Pfister and Hellweg, 2009; Ridoutt and Hung, 2012; Ridoutt and Pfister, 2010; Wichelns, 2017; Yang et al., 2013). For this reason, the WF analysis has been extended to move from water use to *scarce* water use. The concept proposed in the literature is the Scarce Water Footprint (SWF: White et al, 2011), weighting the volume of water by an impact indicator, as for example the Water Stress Index (WSI).

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[4] Bonamente et al. (2000) calculate the water footprint of Italy but without using input-output analysis.

[5] Despite the claim to use the WEBT methodology the results seems to yield from aa complete MRIO analysis.

The concept of scarce water footprint (or scarcity-weighted water footprint) has been developed in the field of Life Cycle Assessment (LCA) studies (Ridoutt and Pfister, 2010; Ridoutt and Pfister, 2013; Pfister, 2011) and is recommended as a guideline in the ISO 14046 water footprint document (ISO, 2014; Vanham et al., 2018). The approach emerged as a result of the criticism of the volumetric water footprint (Mekonnen and Vanham, 2021). A first problem is that volumetric WF is tailored to support the study of water scarcity at the global level, while water scarcity and quality mostly are regional and local issues. Another aspect that the volumetric footprint does not take into account is the fact that water withdrawals varies according to seasons and geographical locations. From an economic point of view, there is a huge variation in the opportunity cost of a crop grown in Sri Lanka and another in the Jordan Valley (Assaf el al., 2007), or between cultivation in the wet and in the dry season; the volumetric WF is unable to capture this variation in opportunity costs. Controversial is also the idea that production could be moved efficiently from areas with green water scarcity to areas with water abundance with the aim of minimizing the global water footprint (Hoekstra, 2016).

A large number of reports in the literature use the SWF concept to calculate water consumption. A group of papers use the approach to analyze the loss of freshwater catch resulting from excessive water consumption (Hanafiah et al., 2011) and to examine the global footprint of food products (Ridoutt and Pfister, 2010 and 2013). Pfister et al. (2011) calculate the specific water consumption and land use for the production of 160 crops and crop groups, covering most harvested mass on global cropland and quantifying indicators for land and water scarcity with a high geospatial resolution. Pfister and Bayer (2014) use the monthly WSI to calculate the water consumption of global crop production with reference to 11.000 watersheds. The study by White et al. (2015) calculates the WF and SWF considering blue water withdrawals in the Haihe River Basin in China, using the MRIO method to account for external footprint. Wang et al. (2015) make a comparison between the WF and SWF for the grain products in China. Ridoutt et al. (2018) use spatially explicit water-scarcity factors and a spatially disaggregated Australian water-use account to develop water-scarcity extensions of a MRIO model. Zhang et al. (2018) investigate water use in agricultural production in the environmentally sensitive Lake Dianchi Basin in China, considering the WF and SWF. At international scale, the study of Lenzen et al. (2013) use the WSI at a country level, to calculate WF and SWF for 187 countries, considering blue and green water and adopting the MRIO approach.

In this study a stress indicator is used considering blue and grey water together (Water Requirement Index: WRI). This is also consistent with considering WF grey and blue as drivers of impacts on freshwater ecosystems (Ridoutt and Pfister, 2010; Chapagain et al.,2006; Chapagain and Orr, 2009). Two countries with the same WSI for blue water, when considering also grey water could be found in a quite different condition.

From an even broader point of view, water scarcity is not only a natural problem, but is also related to the scarcity of social resources available to overcome the natural resources constraints. The transformation of natural issues into social issues occurs at various levels. The first level concerns scarcity due to the increase in demand, which from a social point of view may generate regional and local conflicts as a result of increased engineering efforts to increase supply. At a second level, when it is no possible to further increase the water supply and the only solution is to increase efficiency in water use, from a social perspective this implies both improving technology and modifying the institutional framework in order to implement improved water management methods. This is likely to create conflicts for those stakeholders who will be disadvantaged by the normative change.

The new economic incentives and institutional change introduced in the previous phase leads to a quantum leap in water efficiency through maximizing the revenue from every drop of water mobilized in society. There is a redirection of water to the cities, which have higher economic returns than the rural areas; moreover, there is also a change in the supply strategy from self-sufficiency to security of supply, as each country can import the resources it does not have, including water. At this last level, the social challenge is to integrate a larger portion of the population into the modern sector due to the continuous increase in population and the structural dynamics from rural to urban economy. The challenge is enormous as it involves the creation of new jobs in other industries to compensate for the reduction of jobs in agriculture, in parallel with a rapid increase in population and the growth of new needs in people not only for livelihoods, but for better lives (Ohlsson,2000).

The introduction of the social component in the analysis shifts water scarcity from an absolute to a relative concept, in the sense that water management is subject to trade-offs between different social uses (Ohlsson, 2000; Agapitos, 2010). The Social-Scarce Water Footprint (SoSWF) concept considers social trade-offs in the use of water, weighting the WF against the level of achievement of social goals. This is the case of the Social Water Stress Index (SWSI) introduced by Ohlsson (2000).

In this paper we develop a case study with reference to Italy, with a special focus on the external component of WF. We will address the following research questions:

- What are the domestic and the external WF associated with Italy consumption?
- Is the difference between WEBT and MRIO methods relevant in estimating WF?
- What share of Italy's total virtual water use is accounted for by external water footprint?
- In which countries and economic sectors is the Italian pressure on water resources (WF) concentrated?

- What is the scarce (impact based) water footprint (SWF) associated with each country of origin of Italian virtual water imports?
- What is the social-scarce footprint (SoSWF) associated with each country of origin of Italian virtual water imports?
- In which regions and economic sectors are the largest differences between SWF and SoSWF?

For the first time, the pressure exerted by consumption in Italy on the water resources of other regions (43 countries and the rest of the world) is estimated adopting the MRIO approach, considering blue, green and grey water. A disaggregation of the analysis at the industry/country level is also carried out. We compare the volumetric measure of WF with the scarce water footprint (SWF) and the Social Scarce Water Footprint (SoSWF).

The second section of this study presents the data used, the WEBT and MRIO methods to account for virtual water flows, and the methodology used to calculate the SWF and SoSWF. The third section presents the estimates of volumetric water footprint (WF) for Italy, by country of origin and economic sectors, comparing results of the WEBT and MRIO approaches; furthermore, measures of SWF and SoSWF are presented for the countries in which water is actually used to support final consumption in Italy. The fourth section presents a summary and discussion of the main results and provide perspectives for further analysis

2 DATA AND METHODS

2.1 Data

Multiregional input-output databases provide a comprehensive representation of national and international trade (Cazcarro and Arto, 2019). There are several public databases, such as WIOD (Dietzenbacher et al. 2013), EXIOBASE (Tukker et al. 2009, 2013; Wood et al. 2015), EORA (Lenzen et al. 2013; Aldaya et al. 2010), OECD (OECD 2016), GTAP (Narayanan et al. 2012, 2015). These sources of data also contain satellite accounts that allow for environmental economic analysis. For a comparison of these databases, we recommend the reviews by Giljum et al. (2019) and Mangir (2022).

In this study the input-output analysis of water footprints and virtual water flows uses data from the WIOD for 2014 as its main source (WIOD, 2016). WIOD is considered one of the major databases on international production and trade, with satellite accounts related to environmental and socio-economic indicators across a long time series (from 1995 to 2014). The WIOD provides information for 56 sectors in 43 country (30 Europe, 13 Non Europe) and a region called Rest Of The World and also returns information on the categories of final consumption of households, not-for-profit organizations serving households, government, capital investment, and changes in inventories (Timmer et al., 2012; Timmer et al., 2015; Timmer et al., 2016). Although there are several databases available, WIOD is the most widely used for the study of virtual water trade in the literature for various reasons (Duarte et al.,2016; Alì et al., 2018). First, it provides country-specific information for all EU member states. Second, despite some limitations, the WIOD is the only database providing green, blue, and grey water use for a significant number of industries. Third, the homogeneity of the economic and environmental information provided for more than 15 years allows replicating the analysis for different countries and periods.

Information on direct green, blue, and grey water use in sectors and countries was obtained from the WIOD environmental accounts (Genty, 2012) and is based on the WF studies conducted by Mekonnen and Hoekstra (2011, 2012). In this paper we use data from the 2009 environmental accounts (satellite accounts), as data on the impact of water are still not accounted for following years. This table provides information for 35 industries in 40 countries (27 Europe, 13 Non-Europe). In order to make data consistent with those of 2014 (reference year of the analysis), to the industry in the 2009 table that were disaggregated in 2014 was assigned the same water coefficient. Three countries do not present in the 2009 table are Switzerland, Croatia and Norway; for these states, the water coefficients was equated to those of Austria, Slovenia and Sweden respectively, based on geographical and economic similarity.

Based on the volumes of blue, green and grey water and the outputs by economic sectors of each country, the coefficients of water use per monetary unit of output have been calculated, considering the 2009-2014 change in the value of the US dollar (WIOD currency unit). The assumption corresponds to the non-existence of technological change in the 5 years of differences. A particular case is the Electricity and Water Supply sector, which in the 2014 table is disaggregated into two separate industries. In this case, it would make little to use the same coefficient of the 2009 aggregated sector because the two sub-sectors are very different production activities in the intensity of water use. We adjusted the coefficients to meet the following two conditions: first, the aggregate coefficient of these two industries for 2014, must be equal to the deflated 2009 coefficient; second, the coefficient associated with the water supply industry must be 42 times greater than the coefficient associated with electricity (Kenny et al., 2009; Macknick et al., 2012; Rocchi and Sturla, 2021)., The two sectors, however, are presented together in the results.

2.2 Volumetric WF

We start from the usual linear, input-output model of the production system (Miller and Blair, 2009):

$$x = (I - A)^{-1} y = Ly \quad (1)$$

Where x is the (nx1) vector total output by industry, y is the (n x 1) vector of final consumption, A is the (n x n) matrix of direct requirements (technical coefficients) and I is a conformable identity matrix. The (n x n) matrix L is the Leontief inverse (Leontief, 1941); a single element l_{ij} of the L matrix represents the total value of output from industry j required to produce a (value) unit of output in industry i.

To study WF, the v (n x 1) vector of natural resource use intensity coefficients is defined in terms of volume of water used by each economic sector to produce 1 dollar of output.

$$v = \hat{x}^{-1} W \quad (2)$$

where W is the (nx1) vector of total direct requirement of water by industry (direct water use according to the production-based approach to WF).

Combining equation (1) and (2), the total direct use of water used in the economic system can be expressed as follows:

$$W = \hat{v} L y \quad (3)$$

Where the symbol ^ indicates the diagonalization of vector v.

2.2.1 WEBT Approach

The input-output framework can be easily extended to consider *m* regions and accounting for trade flows among different industries across different regions (Miller and Blair, 2009). The WEBT approach determines the use of water occurring in one region to produce the exports towards another region but does not determine the total consumption of water to produce a given product in a given region/sector, not considering imports of inputs that are usually required to produce the exports. The methodology proposed by Peters (2008) and by Feng et al. (2011), consider *m* regions and *n* economic sectors. According to equation (3) the domestic use of water in region *r* is defined by:

$$W_{Dom}^{r} = \hat{v}^{r} (I - A^{rr})^{-1} y^{rr} \quad (4)$$

Where $\hat{v}^{r}$ is the (nxn) diagonal matrix of water use coefficients in region r, A^{rr} is the (nxn) matrix that represents the inter-industry requirements of goods and services produced in region r and y^{rr} is the (nx1) vector of final consumption of goods and services produced in region r.

The *domestic* water footprint of region *r* is given by the sum (across all economic sectors) of the domestic water use for domestic consumption of good and services and the direct water consumption of households in region *r* (W_{hh}^{r}):

$$WF_{Dom}^{r} = (W_{Dom}^{r})'i + W_{hh}^{r} \tag{5}$$

Where *i* is a (n x 1) vector of ones.

The water embodied in bilateral trade for exports from region *r* to region *s* is defined by:

$$W^{rs} = \hat{v}^{r}(I - A^{rr})^{-1}e^{rs} \quad , \quad r \neq s \tag{6}$$

where e^{rs} is the *(n x 1)* vector of exports from region *r* to region *s*. The WEBT approach considers together both final and intermediate goods exports from region *r* to *s*.

Similarly, the water embodied in bilateral trade for imports of region *r* from region *s* is defined by the (n x 1) vector:

$$W^{sr} = \hat{v}^{s}(I - A^{ss})^{-1}e^{sr} \quad , \quad s \neq r \tag{7}$$

The water embodied in exports from region *r* to all other regions and in imports from all other regions to the region *r* are defined by the following (n x 1) vectors based on equations (6) and (7):

$$W_{Exp}^{r} = \sum_{s \neq r} W^{rs} \tag{8}$$

$$W_{Imp}^{r} = \sum_{s \neq r} W^{sr} \tag{9}$$

The total direct water use (production-based approach) of region r (DW_{Pba}^{r}) and the total water footprint (consumption-based approach) of region r (WF_{Cba}^{r}) are defined as:

$$DW_{Pba}^{r} = WF_{Dom}^{r} + (W_{Exp}^{r})'i \tag{10}$$

$$WF_{Cba}^{r} = DW_{Pba}^{r} - (W_{Exp}^{r})'i + (W_{Imp}^{r})'i \tag{11}$$

Combining equations (12) and (13) the WF can be expressed as:

$$WF_{Cba}^{r} = WF_{Dom}^{r} + (W_{Imp}^{r})'i \tag{12}$$

The total water embodied in imports from single regions to region *r* (W_{Imp}^{rs}), can be easily obtained summing across the imports from the *n* industries of a given region *s*, using equation (7):

$$W_{Imp}^{rs} = (W^{sr})'i \tag{13}$$

2.2.2 MRIO Approach

The WEBT approach described so far allows only to calculate the implicit water trade balance between two regions without accounting for indirect water requirements due to global trade. Production in a given region requires imports of inputs from several countries, generating a corresponding consumption of water. Moreover, the production process in such countries also requires imports from and generates water consumption in other regions, and so on. The pressures on water resources spreads indefinitely through the global production system. To take into account these indirect requirements of water it is necessary to adopt a Multi-Regional Input–Output approach (Peters, 2008).

We follow the methodology used by Feng et al. (2011), Wood (2017) and Arto (2016), considering *n* regions and *m* sectors, yielding disaggregated results by country and economic sector. This methodology captures both the inter-industry and inter-regional interdependency in water use.

The water footprint for a region *r* is calculated considering the Leontief matrix of the global economic system:

$$L^{*} = (I - A^{*})^{-1} \tag{14}$$

where A^{*} is the (nm x nm) matrix of direct requirements coefficients for *n* industries in *m* regions.

The A^{*} and L^{*} matrices are composed by m^2 sub-matrices of dimension (n x n):

$$A^{*} = \begin{bmatrix} A^{11} & \dots & A^{1m} \\ \vdots & \ddots & \vdots \\ A^{m1} & \dots & A^{mm} \end{bmatrix} \tag{15}$$

$$L^* = \begin{bmatrix} L^{11} & \dots & L^{1m} \\ \vdots & \ddots & \vdots \\ L^{m1} & \dots & L^{mm} \end{bmatrix} \quad (16)$$

The A^{rr} elements along the main diagonal of matrix A^* are the matrices of technical coefficients representing inter-industry interdependencies within single regions, while a single element of each sub-matrix A^{rs} is calculated as:

$$a_{ij}^{rs} = \frac{z_{ij}^{rs}}{x_i^s} \quad (17)$$

where the z_{ij}^{rs} is the trade from industry *i* in region *r* to industry *j* in region *s* and x_i^s is the total output of industry *i* in region *s* (interindustry-interregional trade).

The (nm x 1) vector W_E of direct water use associated to production in each one of the *m* regions, disaggregated by industry (in a similar way that equation (3)) is given by:

$$W_E = \hat{v}^* L^* Y^* i' \quad (18)$$

where Y^* is the (nm x m) matrix of final demand from the *m* regions towards *n* different industries in *m* different regions and *i* is a (1 x m) vector of ones.

Equation (18) allows to calculate the direct use of water for the production of goods and services in the global economy, disaggregated by industry and region. This equation corresponds to the water used within the economic system, that is, it does not include household consumption as part of the domestic water footprint of each country[6].

The availability of disaggregated data of equation (18) allows calculating not only direct use of water in single regions, as in equation (4), but also WF as in equation (10) and (11), taking into account also for feedback effects due to re-imports of exported goods and services (Moran 2017). Appendix 1 provides a detailed description of these calculations for a global value chain subdivided into 3 regions.

The estimates of interest based on the MRIO methodology for this paper are the amount of water associated with domestic production consumed in Italy

[6] This part is aggregated for the case of Italy as in the equation (5).

(domestic economic water footprint[7]) and the water associated with imports of final goods consumed in Italy (external water footprint), classified by country and economic sector. We will also estimate the water exports from Italy, the direct use of water (production-based concept of water footprint), and the water imports for exports (water re-exports: van Oel et al.(2019)). See Appendix 1 for the description of this method.

To include corrections to the water coefficients by a single factor for each region, equation (18) can be modified by including a (nm x nm) matrix $\widehat{\Phi}$ with *m* diagonal matrices of *m* equal elements with the correction factors by region:

$$W_{E\_Mod} = \widehat{\Phi} \cdot \hat{v}^{*} L^{*} Y^{*} i' \qquad (19)$$

Appendix 2 details the way in which the calculation of W_{E_Mod} is performed considering the change in coefficients based on the WSI and SWSI (presented in the following two sections) to calculate the SWF and SoSWF associated with a particular country.

2.3 Water Stress Index (WSI)

Water stress is commonly defined as the ratio of total annual freshwater withdrawals to total freshwater availability. In this paper we use the concept of the Water Stress Index developed by Pfister et al. (2009) and White et al. (2015). WSI is an important information for assessing the impact of freshwater use, since one liter of water consumed in a water scarce region is likely to have a higher impact than in a water rich region (Gheewala et al., 2018). Pfister et al. (2009) advances a concept to calculate a WSI between 0 (no water stress) and 1 (maximum stress), which is used in the LCA analysis as a characterizing factor for analyzing "water deprivation" to indicate the portion of renewable resources subtract to other uses. (White et al., 2015).

To calculate the WSI Pfister et al. (2009) consider the ratio of total annual freshwater withdrawals to hydrological availability (Withdrawal To Availability ratio, WTA), which corresponds to the sum of total blue water withdrawals divided by the total long-term water availability (including the ecological flow). Lenzen et al. (2013) use the Water Exploitation Index (WEI) which corresponds to the percentage of total *actual* blue renewable freshwater resources withdrawn considering withdrawals net of discharges and still without subtracting the ecological flow to total long-term availability.

An interesting indicator available for several years is the 6.4.2 SDG indicator, approved by the IAEG-SDGs under the UN, with the FAO as custodian (FAO,

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[7] In this study the expression "domestic economic water footprint" is used to refer to that part of the domestic water footprint generated in the economic system, i.e., the domestic water footprint minus direct household consumption.

2022). The indicator is computed as the total freshwater withdrawn (TFWW) divided by the difference between the total renewable freshwater resources (TRWR) and the environmental flow requirements (EFR), multiplied by 100. (FAO, 2022; Dickens te al., 2019).

$$SDG_{Ind} = \frac{TFWW}{TRWR-EFR} * 100 \quad (20)$$

A value below 25% conventionally indicates a safe situation in which there is a minimal impact on resources and competition between users; above 25% the indicator could depict situations potentially problematic, up to the extreme case where the stress level exceeds 100%, indicating that total water withdrawals are exceeding the amount of "allocable" water available and affecting the ecological flow.

The study by Guan and Hubacek (2008) calculates the extended water demand corresponding to the net demand for blue water (withdrawals minus discharges) plus grey water based on an economic input-output model; however, this study does not calculate a ratio with respect to availability. Rocchi and Sturla (2021) calculate the ratio between extended demand and feasible supply for the case of Tuscany in Italy, where feasible supply corresponds to long-term groundwater recharge and surface runoff net of ecological flow, with corrections associated with periods of high surface runoff that do not influence the value of the index when average hydrology is considered.

In this paper we consider both blue and grey water to calculate the scarce water footprint. Grey water is included according to the logic of take into account in the analysis all factors that affecting water resources. We consider both the volume of water used *and* the quality of water expressed in terms of volume: grey water becomes an extension of blue water demand. For consistency in scarcity weighting, a Water Requirements Index (WRI) is proposed to be used in the calculation of WSI at the national level. The WRI corresponds to the ratio of blue *and* grey water to the feasible long-term water availability (average runoff plus average groundwater recharge, minus economic flow, minus economic flow)[8] (equation 21).

The denominator (availability) is defined as in the SDG indicator, that for the mean values it converge to the feasible supply, while the numerator (requirements) considers both blue water and grey water obtained on the basis of WIOD information.

$$WRI = \frac{Blue\ Water + Gray\ Water}{Feasible\ Supply} * 100 \quad (21)$$

[8] This indicator does not correspond exactly to the one proposed by Rocchi and Sturla (2021) since it does not consider net demand, but rather abstractions, as the WIOD environmental database does.

The relation between WRI and the WSI is not linear, the latter being adjusted according to a logistic function that returns continuous values between 0 and 1 (Pfister et al., 2009):

$$WSI = \frac{1}{1 + e^{-6,4 \cdot WRI \cdot (\frac{1}{0,01} - 1)}} \qquad (22)$$

WSI has a minimal water stress of 0.01 as any water consumption has at least a marginal local impact (Pfister et al., 2009).

This version of the WSI is more prudent than the one defined on the basis of WTA, WEI or SDG indicators, as the WRI is higher than these indicators and, therefore, a higher impact is associated to water use[9].

2.4 Social Water Stress Index (SWSI)

The capacity of society to respond to difficult challenges is assessed by UNDP through the Human Development Index (HDI). The human development index measures the average achievements in a country in three basic dimensions of human development - longevity, knowledge and a decent standard of living. A composite index, the HDI thus contains three variables: life expectancy, educational attainment and real GDP per capita (Ohlsonn, 2000); the value is in a range between 0 and 1.

The social water stress index (SWSI) is obtained by dividing the WSI by the HDI:

$$SWSI = \frac{WSI}{HDI} \qquad (23)$$

This equation indicates a greater exacerbation of water scarcity as the human development index decreases. This leads to an increase in the SWSI compared to the WSI, the trade-off of social benefits being expressed as a deterioration in water conditions. The value of the index could in theory vary between 0 and infinitive; values higher than 1 are adjusted to unit.

3 Results

3.1 Water Footprint of Italy: WEBT and MRIO estimates

[9] The curve is tuned to result in a WSI of 0.5 for a WTA of 0.4, which is the threshold between moderate and severe water stress (Pfister et al., 2009).

Table 1 and Table 2 present the aggregated results considering the two approaches WEBT and MRIO to WF. Italy's water footprint for 2014 corresponds to 137,415 Mm^3 with WEBT and 136,543 Mm^3 with MRIO, with an overall difference of 0.6%. The external water footprint corresponds to 82,518 Mm^3 and 81,491 Mm^3, respectively, representing a 60% of the total; the difference between the two methodologies is 1.2%. The blue water footprint represents only 20% of the total WF, the green WF 64% and the grey WF 16%, with very similar values in both approaches.

Table 1. Water use for Italy considering WBTE Approach
(Millions of cubic meters, Mm^3)

Variable	Blue Water	Green Water	Grey Water	Total
Household Consumption	847	0	4,085	4,932
Domestic Economic Water Footprint	12,700	31,565	5,700	49,965
External Water Footprint (Imports)	13,480	56,139	12,899	82,518
Water Embodied in Exports	3,881	13,965	4,165	22,011
Direct Use of Water (Production-based)	16,581	45,530	9,865	71,976
Water Footprint (Consumption-based)	27,027	87,704	22,684	137,415

Source: own elaboration on WIOD data

Table 2. Water use in Italy considering MRIO Approach
(Millions of cubic meters, Mm^3)

Variable	Blue Water	Green Water	Grey Water	Total
Household Consumption	847	0	4,085	4,932
Domestic Economic Water Footprint	12,742	31,640	5,738	50,120
External Water Footprint (Imports)	13,081	56,157	12,253	81,491
Water Embodied in Exports	3,840	13,890	4,005	21,735
Direct Use of Water (Production-based)	16,581	45,530	9,865	71,976
Water Footprint (Consumption-based)	26,670	87,797	22,076	136,543

Source: own elaboration on WIOD data

The results for the 56 industries have been aggregated into 5 macro-sectors: Agriculture; Food Industry; Electricity, Gas and Water Supply; Manufacture; and Services (see Appendix 2). Table 3 and Table 4 present the domestic (excluding household direct consumption) and external economic WF of Italy, disaggregated by industry and by water type, according with the WEBT and MRIO methodology. The results are very similar for the domestic footprint (the largest difference occurring for Manufacture with a value 2.8%) while larger differences emerge in the external footprint, especially in Manufacture (11.1%) and Services (12.3%). The WF of the Manufacture sector is the one with the largest external component (87% of the total) while the WF of the Food Industry sector is the one with the smallest external component (40% of the total). The differences between WEBT and MRIO are accentuated in the sectors with a higher external water footprint component, because the WEBT methodology does not capture the interregional cut-off effects (consistent with the results of Feng et al. (2011)). However, the differences are not relevant, as illustrated in Figure 1.

Table 3. Sectoral Econ-Domestic and External Water Footprint WEBT Approach (Millions of cubic meters, Mm^3)

Economic Sector	WEBT - Sectoral Econ-Domestic WF				WEBT - Sectoral External WF			
	Blue	Green	Grey	Total	Blue	Green	Grey	Total
Agriculture	3,373	31,565	4,010	38,949	6,352	56,139	5,744	68,234
Food Industry	110	0	650	760	60	0	445	505
Electricity, Gas and Water Supply	9,041	0	0	9,041	6,373	0	0	6,373
Manufacture	160	0	943	1,103	689	0	6,651	7,340
Services	16	0	97	114	6	0	60	66

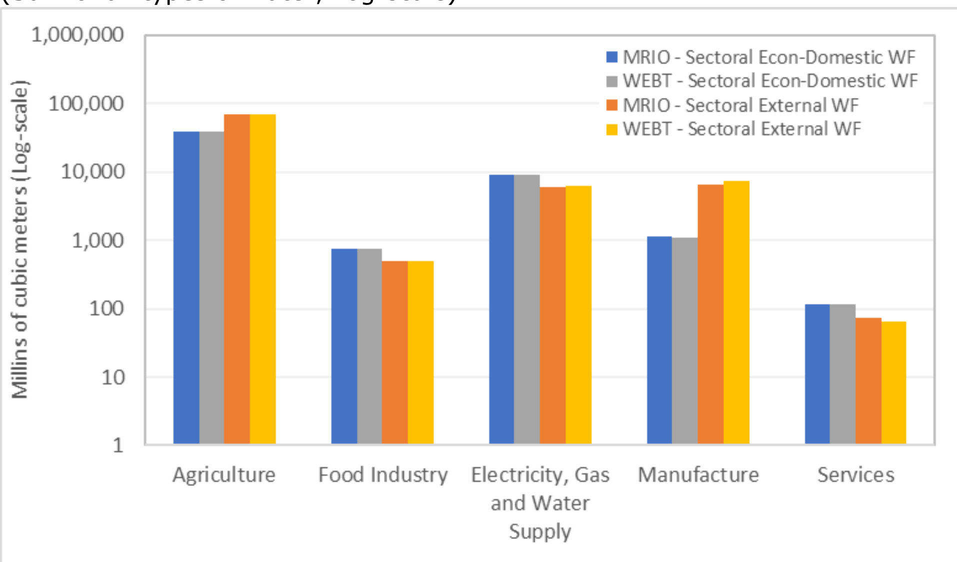
Source: own elaboration on WIOD data

Table 4. Sectoral Econ-Domestic and External Water Footprint MRIO Approach (Millions of cubic meters, Mm^3)

Economic Sector	MRIO - Sectoral Econ-Domestic WF				MRIO - Sectoral External WF			
	Blue	Green	Grey	Total	Blue	Green	Grey	Total
Agriculture	3,381	31,640	4,020	39,041	6,349	56,157	5,746	68,252
Food Industry	110	0	651	761	60	0	443	504
Electricity, Gas and Water Supply	9,069	0	0	9,069	6,055	0	0	6,055
Manufacture	165	0	970	1,135	610	0	5,996	6,606
Services	17	0	97	114	7	0	68	75

Source: own elaboration on WIOD data

Figure 1. Comparison WEBT and MRIO. Econ-Domestic and Sectoral WF (Sum of all types of water, Log-scale)



Source: own elaboration on WIOD data

When considering the breakdown by country of origin of virtual water and by economic sector, the differences between the methodologies are more notable (Table 5). Looking at the external WF for the 42 countries included in the WIOD and the Rest of The World, the differences between the WEBT and MRIO methodologies can vary up to 68% (Latvia). Among the 10 countries with the highest external water footprint values, France (12%), the United States of America (14%) and Hungary (15%) show the largest differences.

The country receiving from consumption in Italy the largest pressure on its water resources in absolute terms is China (6,794 Mm^3 WEBT, 6,973 Mm^3 MRIO), followed by Brazil (4,557 Mm^3 WEBT and 6,973 Mm^3 MRIO). The 42 countries of the WIOD represent 56% of the Italian external water footprint (46,061 Mm^3 WEBT and 45,984 Mm^3 MRIO) the Rest of the World accruing for the remaining 44% (36,457 Mm^3 WEBT and 35,507 Mm^3 MRIO).

Table 5. External WF by Country. WEBT and MRIO approaches
(Millions of cubic meters, Mm^3)

Country	WEBT	MRIO	Difference
Rest of the World	36,457	35,507	-3%
China	6,794	6,973	3%
Brazil	4,557	4,936	8%
France	3,683	3,231	-12%
United States of America	3,386	3,863	14%
Spain	3,278	3,191	-3%
India	2,905	2,820	-3%
Indonesia	2,442	2,289	-6%
Hungary	2,275	1,937	-15%
Germany	1,968	1,970	0%
Turkey	1,926	1,866	-3%
Canada	1,918	1,808	-6%
Russian Federation	1,592	1,642	3%
Poland	1,278	1,374	8%
Romania	1,244	1,139	-8%
Bulgaria	822	775	-6%
Austria	712	588	-17%
Australia	679	771	14%
Czechia	474	573	21%
Switzerland	468	429	-8%
Ireland	382	337	-12%
Greece	350	301	-14%
Denmark	314	356	13%
Croatia	275	225	-18%
Mexico	252	246	-2%
Slovenia	236	177	-25%
Belgium	227	238	5%
Sweden	211	231	10%
Netherlands	204	209	3%
United Kingdom	185	220	19%
Slovakia	180	204	13%
Portugal	179	182	1%
Lithuania	165	242	47%
Taiwan	136	160	18%
Finland	117	116	-1%
Norway	72	105	46%
Latvia	66	111	68%
Estonia	49	68	39%
Korea	24	31	30%
Japan	19	32	66%
Luxembourg	6	9	41%
Cyprus	5	5	1%
Malta	3	3	-1%

Source: own elaboration on WIOD data

Table 6 and Table 7 show the breakdown of external WF by economic sector for both the methodologies. The Services sector is the one showing the largest difference between WEBT and MRIO. The values are almost negligible, however, except in the case of Manufacture where the difference is 11% on average between the methodologies. Such a difference is mainly explained by the greater extension of the value chain of this sector compared to sectors such as Agriculture and the Food Industry; the larger the value chain, the more important are the inter-regional cut-off effects (Moran et al., 2017).

Table 6. External WF by Industry. WEBT Approach.
(Top 10 countries with the largest Italian external WF)
(Millions of cubic meters, Mm^3)

Country	WEBT Approach				
	Agriculture	Food Industry	Electricity, Gas and Water Supply	Manufacture	Services
China	4,374	41	646	1,733	0
Brazil	4,378	7	128	44	0
France	3,136	63	193	290	1
United States of America	3,157	15	39	170	4
Spain	3,169	2	92	15	0
India	2,378	6	21	500	0
Indonesia	2,430	3	6	3	0
Hungary	2,208	9	1	55	2
Germany	1,701	10	69	187	1
Turkey	1,770	0	70	86	0

Source: own elaboration on WIOD data

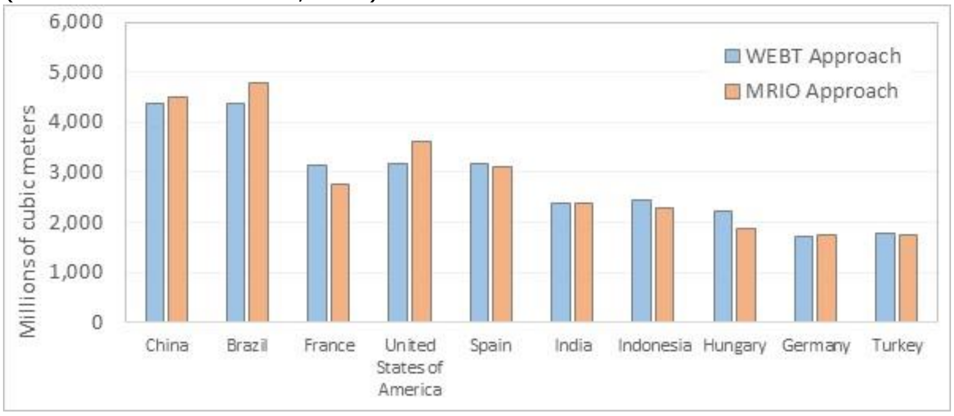
Table 7. External WF by Industry. MRIO Approach.
(Top 10 countries with the largest Italian external WF)
(Millions of cubic meters, Mm^3)

Country	MRIO Approach				
	Agriculture	Food Industry	Electricity, Gas and Water Supply	Manufacture	Services
China	4,496	43	676	1,758	0
Brazil	4,776	8	119	33	0
France	2,772	60	161	236	1
United States of America	3,615	18	46	176	9
Spain	3,099	2	78	12	0
India	2,372	6	21	421	0
Indonesia	2,275	3	7	4	0
Hungary	1,876	9	1	50	2
Germany	1,759	10	56	145	1
Turkey	1,733	0	62	71	0

Source: own elaboration on WIOD data

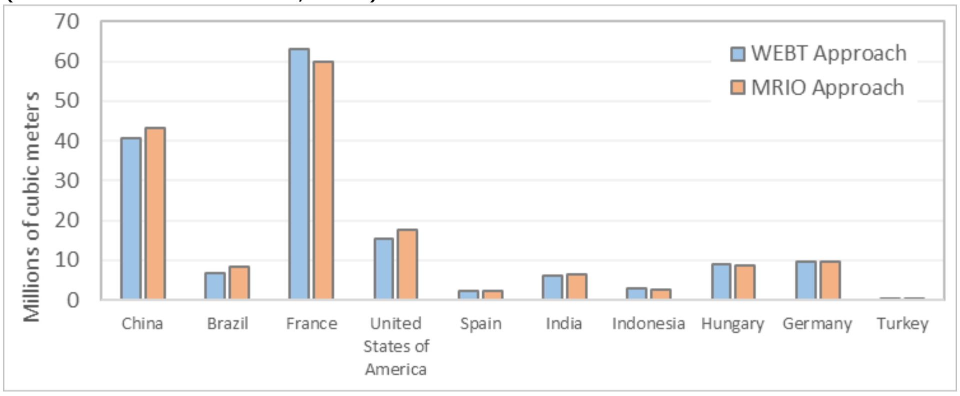
The industry disaggregation of the external WF is illustrated in Figures from 2 to 6, where it can be seen that for Agriculture the country with the highest value is Brazil, France for the Food Industry, China for Electricity, Gas and Water Supply and for Manufacture it and USA for Services. It can also be seen that the greatest difference between WEBT and MRIO occurs in the Services sector (overall showing small values) followed by the Manufacture sector as previously mentioned.

Figure 2. Agriculture External WF. WEBT and MRIO approaches.
(Top 10 countries with the largest Italian external WF)
(Millions of cubic meters, Mm^3)



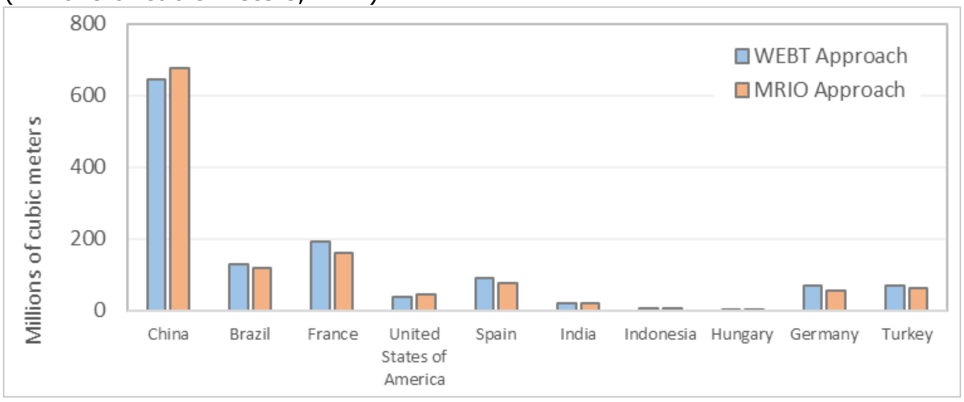
Source: own elaboration on WIOD data

Figure 3. Food Industry External WF. WEBT and MRIO approaches.
(Top 10 countries with the largest Italian external WF)
(Millions of cubic meters, Mm^3)



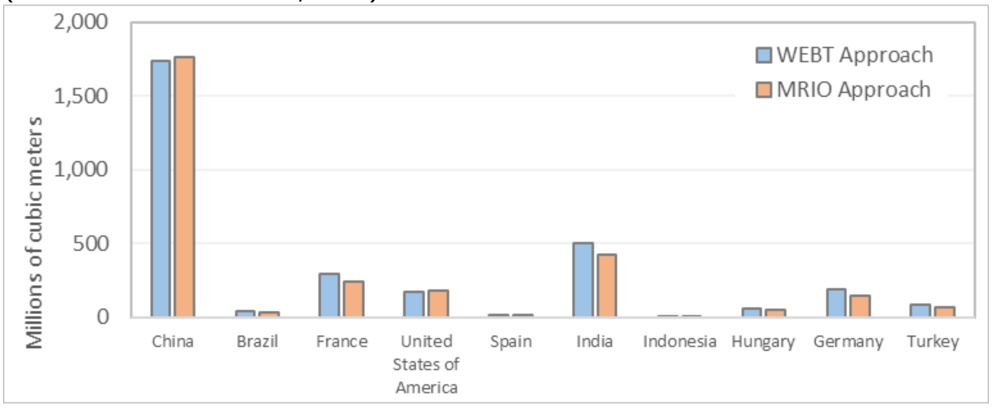
Source: own elaboration on WIOD data

Figure 4. Electricity, Gas and Water Supply External WF.
WEBT and MRIO approaches.
(Top 10 countries with the largest Italian external WF)
(Millions of cubic meters, Mm^3)



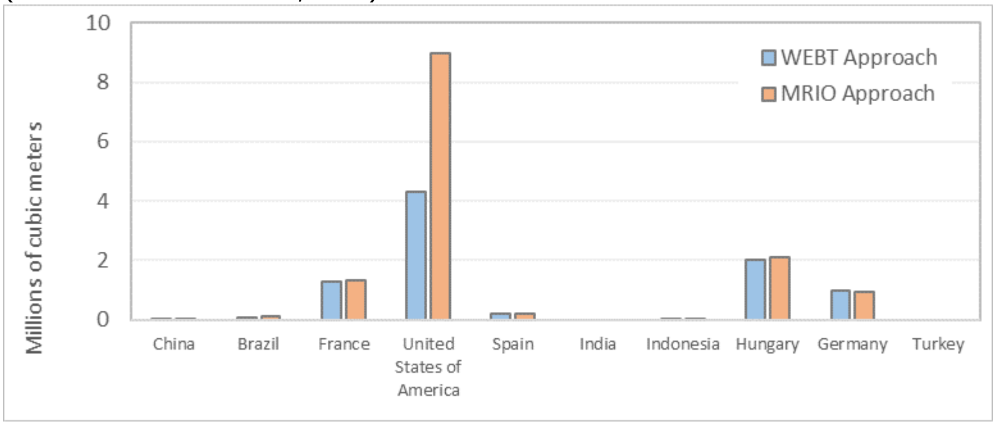
Source: own elaboration on WIOD data

Figure 5. Manufacture External WF. WEBT and MRIO approaches.
(Top 10 countries with the largest Italian external WF)
(Millions of cubic meters, Mm^3)



Source: own elaboration on WIOD data

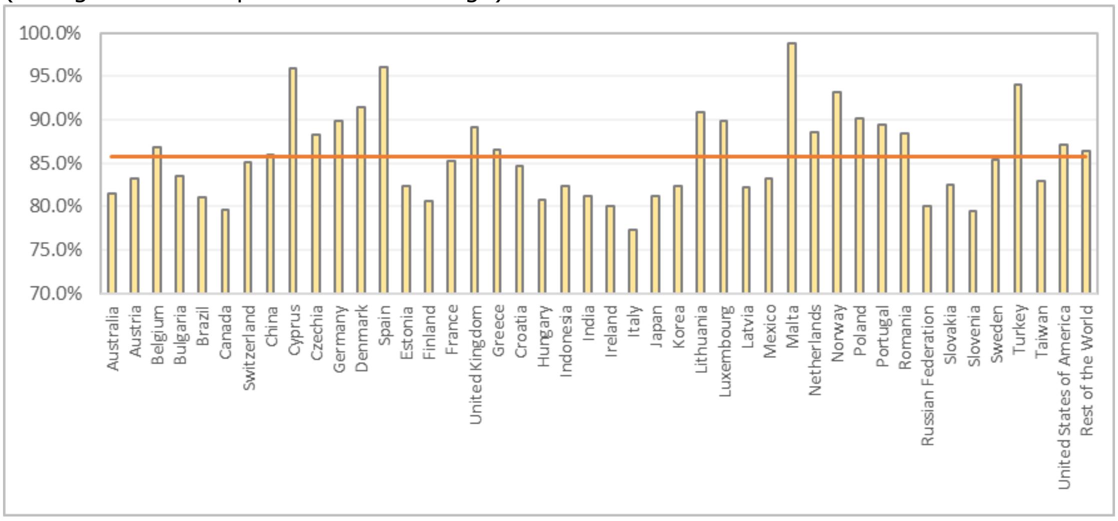
Figure 6. Services External WF. WEBT and MRIO approaches.
(Top 10 countries with the largest Italian external WF)
(Millions of cubic meters, Mm^3)



Source: own elaboration on WIOD data

The MRIO methodology considers as a component of the WF only those virtual water imports associated with Italian final consumption. However, there is a component of virtual water imports destined to the production of goods exported by Italy, the so-called water re-exports (van Oel et al., 2019). Based on the water re-exports for each country, it is possible to obtain the total virtual water exports (not to be confused with external WF), which allows to know the percentage of virtual water coming from a given country that can be considered an actual water footprint associated with Italian consumption. Figure 7 presents this percentage per country (blue, green and grey water), including Italy (percentage of Italy's economic direct use of water that are used in Italian consumption). On average, only 85.8% of total virtual water imports are actually driven by Italian final consumption. Countries with a percentage higher than 95% are Malta (98.8%), Cyprus (95.9%) and Spain (96.0%). Countries with a percentage lower than 80% correspond to Canada (79.6%) and Slovenia (79.4%). In the case of Italy, the percentage is 77.3%, which means that Italy contributes with the highest percentage of water resources to Italian exports.

Figure 7. Percentage of Water Imports driven by Italian Consumption (by Country) (Orange line corresponds to the average)



Source: own elaboration on WIOD data

3.2 WF, SWF and SoSWF

Hereafter, the WF calculated with the MRIO approach is used, as the one better representing the pressure exerted by Italian consumption on water resources in other regions (Feng et al., 2011; Peters, 2008; Duarte et al., 2016; Arto et al., 2016; Wood 2017). Results are compared for Volumetric Water Footprint (WF), Scarce Water Footprint (SWF) and Social-scarce Water Footprint (SoSWF).

3.2.1 Volumetric Water Footprint

The total Italian WF amount to 136,542 Mm^3, most of which is external (81,491 Mm^3 representing 59.7% of the total). The largest sectoral component corresponds to agriculture (78.6%), followed by the Electricity-Gas-Water Supply sector (11.1%). Table 8 presents the breakdown by industry and region of the Italian WF.

Table 8. Italian WF by Industry and Region (MRIO approach)

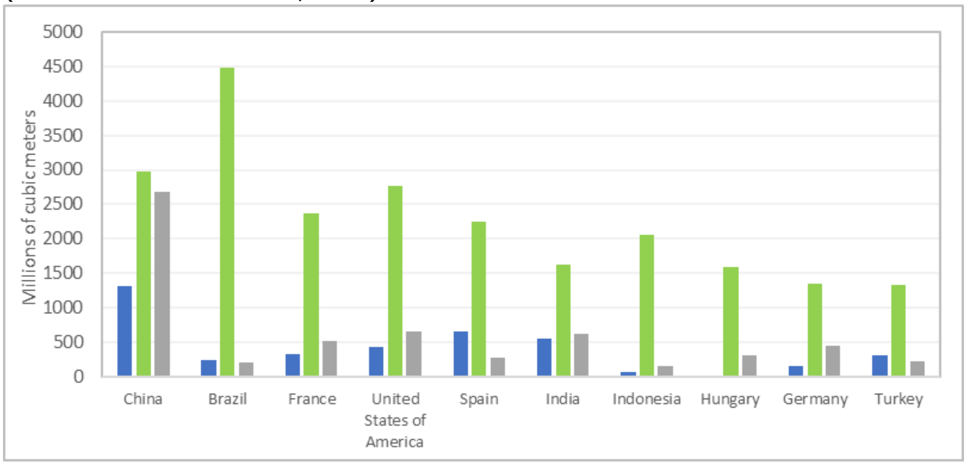
Economic Sector	Italy (Mm^3)	42 WIOD Countries (Mm^3)	Rest of The World (Mm^3)	Total WF (Mm^3)	% Total
Agriculture	39,041	38,514	29,738	107,293	78.6%
Food Industry	761	363	140	1,265	0.9%
Electricity, Gas and Water Supply	9,069	2,639	3,416	15,123	11.1%
Manufacture	1,135	4,444	2,162	7,741	5.7%
Services	114	24	51	189	0.1%
Households Consumption	4,932	0	0	4,932	3.6%
Total	55,052	45,984	35,507	136,542	100.0%

Source: own elaboration on WIOD data

Figure 8 shows the distribution of the external water footprint by type of water: blue, green and grey; considering the top 10 countries in the external WF of Italy. For blue water, the country with the largest contribution is China

(1,318 Mm^3, 10% of total blue water virtual import), for green water Brazil (4,475 Mm^3, 8% of total) and for grey water China (2,684 Mm^3, 22% of total grey water). The Rest of The World accounts for blue, green and grey water respectively with 6,677 Mm^3 (53% of total blue water), 25,022 Mm^3 (53% of total green water) and 3,508 Mm^3 (53% of total grey water).

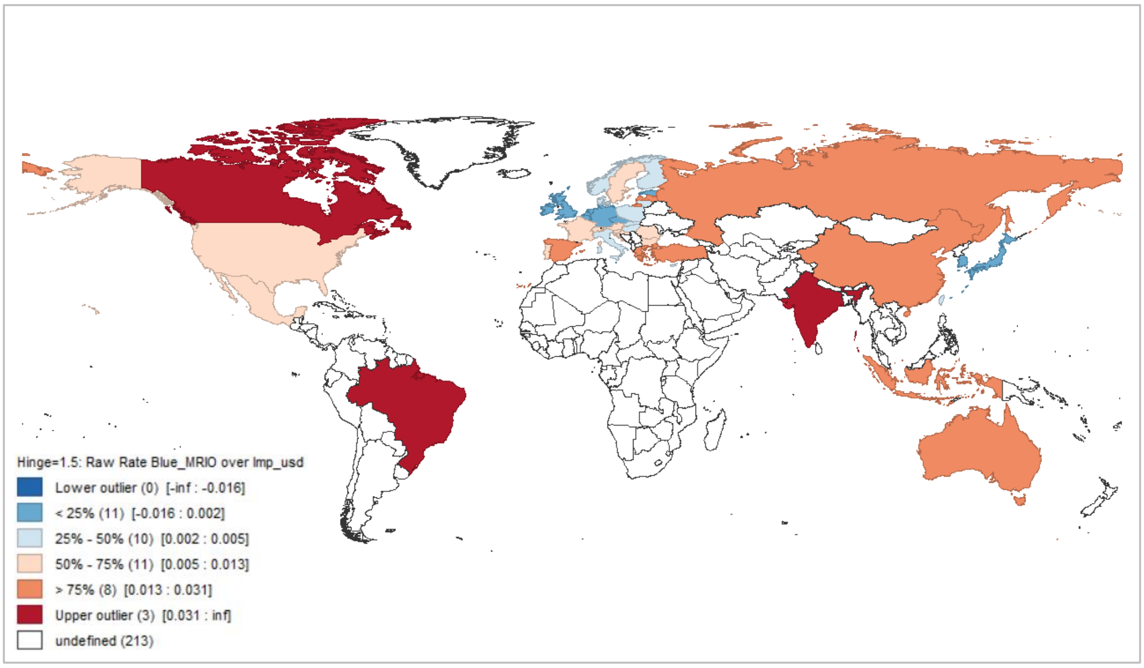
Figure 8. Distribution of Blue, Green and Grey External WF
(Top 10 countries with the largest Italian external WF)
(Millions of cubic meters, Mm^3)



Source: own elaboration on WIOD data

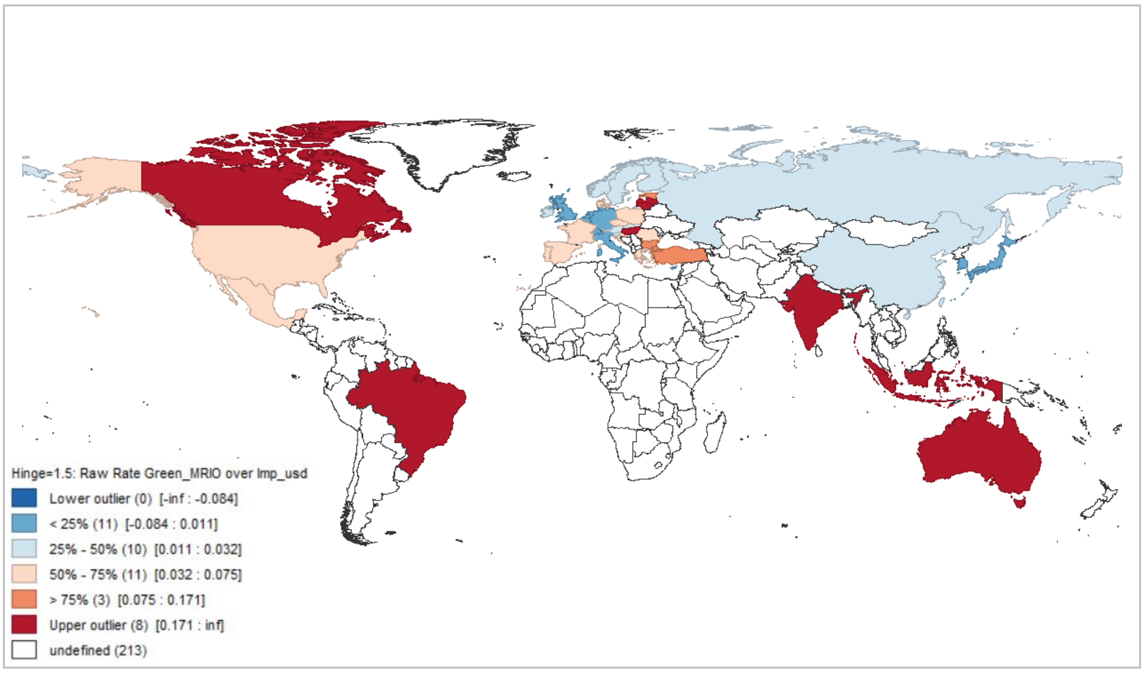
For a better illustration, the maps in Figures 9 to 12 show Italy's external water footprint normalized by the value of imports (direct and indirect) in the 42 WIOD countries for blue, green, grey and total water, respectively.

Figure 9. External Blue Water Footprint intensity. MRIO approach.
(Cubic meters by US dollar of direct and indirect imports)



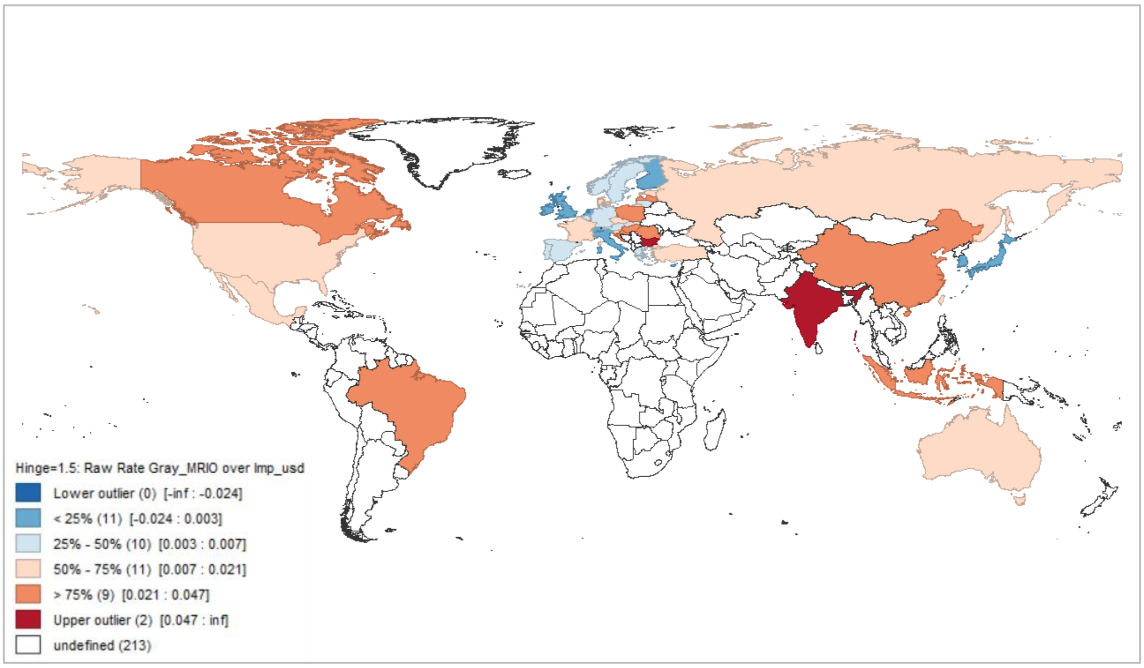
Source: own elaboration on WIOD data

Figure 10. External Green Water Footprint intensity. MRIO approach.
(Cubic meters by US dollar of direct and indirect imports)



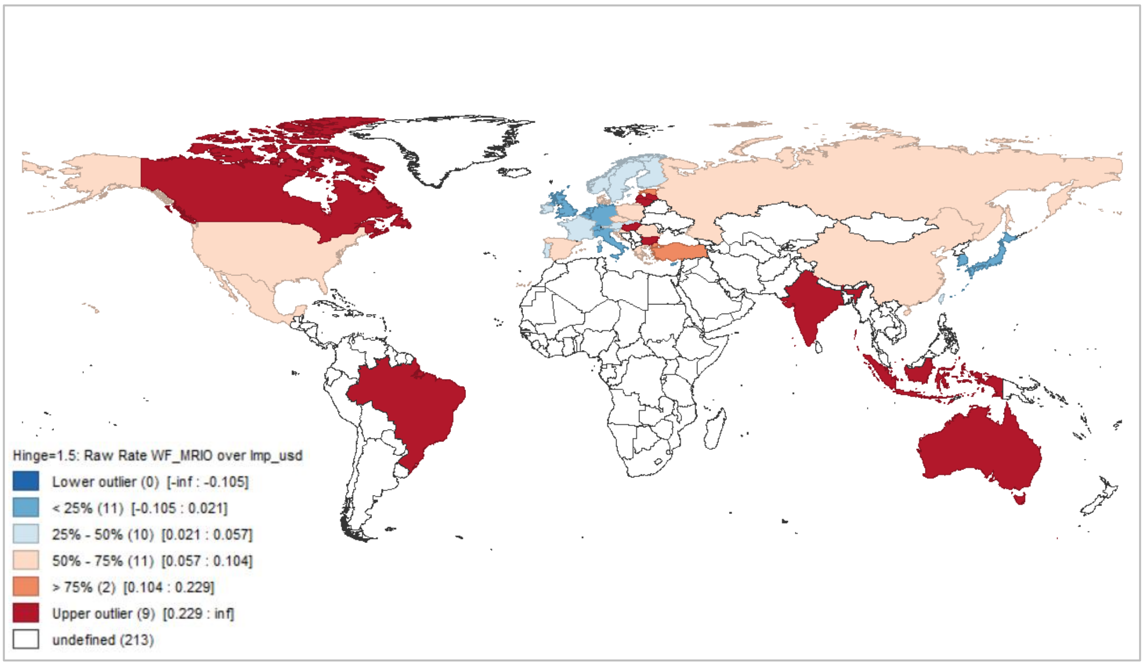
Source: own elaboration on WIOD data

Figure 11. External Grey Water Footprint intensity. MRIO approach.
(Cubic meters by US dollar of direct and indirect imports)



Source: own elaboration on WIOD data

Figure 12. External Total Water Footprint intensity. MRIO approach.
(Cubic meters by US dollar of direct and indirect imports)



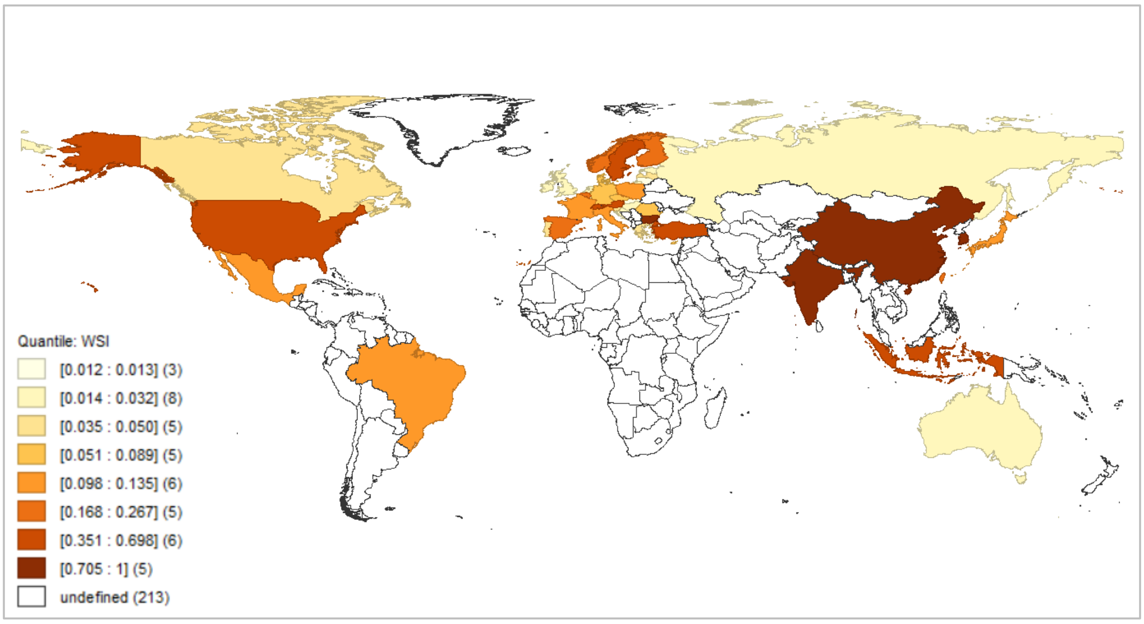
Source: own elaboration on WIOD data

3.2.2 Scarce Water Footprint

The SWF calculation has been made considering only blue and grey water uses, the component of WF generating impacts on environmental flows necessary for the health of the freshwater ecosystems, while green water use is mostly linked to impacts of land use (Ridoutt and Pfister, 2010). The external SWF (42 countries and the Rest of The World) and the internal SWF of Italy (including direct household consumption) are considered.

The map in Figure 13 shows the geographic pattern of water stress in the world resulting from the WIOD database, considering blue and grey water (WSI based on WRI indicator).

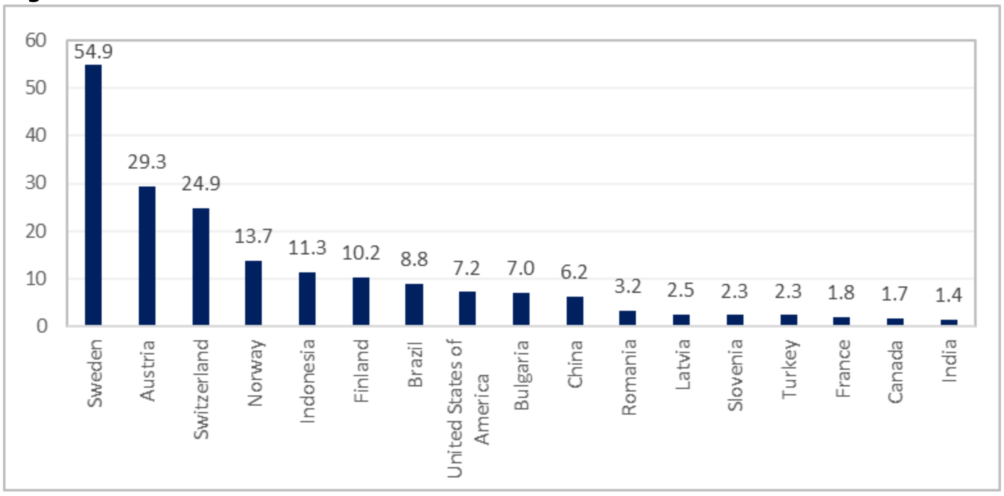
Figure 13. Water Stress Index (WSI) by Country



Source: own elaboration on WIOD data

Figure 14 shows the difference between the calculation of WSI using the SDG indicator of pressure on water resources (considering only blue water) and with the WRI indicator (blue and grey water) proposed in this study. The countries in which the difference exceeds 100% (WRI is at least 2 times greater than SDG) are shown. The effect of considering grey water for the calculation of the WSI is significant, which confirms the need to include it.

Figure 14. Ratio between the calculation of WSI with WRI and SDG



Source: own elaboration on WIOD data

The pressures exerted by Italian consumption on global water resources depends on the sector and geographic composition of imports. The total SWF for Italy corresponds to 16,536 Mm^3 corresponding to 33.9% of its blue and volumetric water footprint (WF_bg). Interestingly, Italian consumption generate a lower average impact on domestic than external water resources (6.4%). The largest amount of the SWF of Italy (7,221 Mm3, about 44% of the total) is concentrated in the 42 WIOD Countries, with a 48.6% average ratio over the volumetric measure of WF. However, the Rest of the World has a 63.7% average ratio over the volumetric measure of WF, due to the higher average water stress existing in these countries (Table 9).

Table 9. Italy's Scarse Water Footprint (SWF) by Region
(Millions of cubic meters, Mm^3)

Region	Italy	42 WIOD Countries	Rest of the World	Total
WF_bg	23,412	14,848	10,485	48,745
SWF	2,634	7,221	6,681	16,536
SWF/WF_bg	11.3%	48.6%	63.7%	33.9%

Source: own elaboration on WIOD data

Table 10 presents the breakdown of the Italian external water footprint (WF_bg), the water stress index (WSI) and the external scarce water footprint (SWF) for the 43 regions.

Table 10. Italy's External Scarse Water Footprint (SWF) by Country

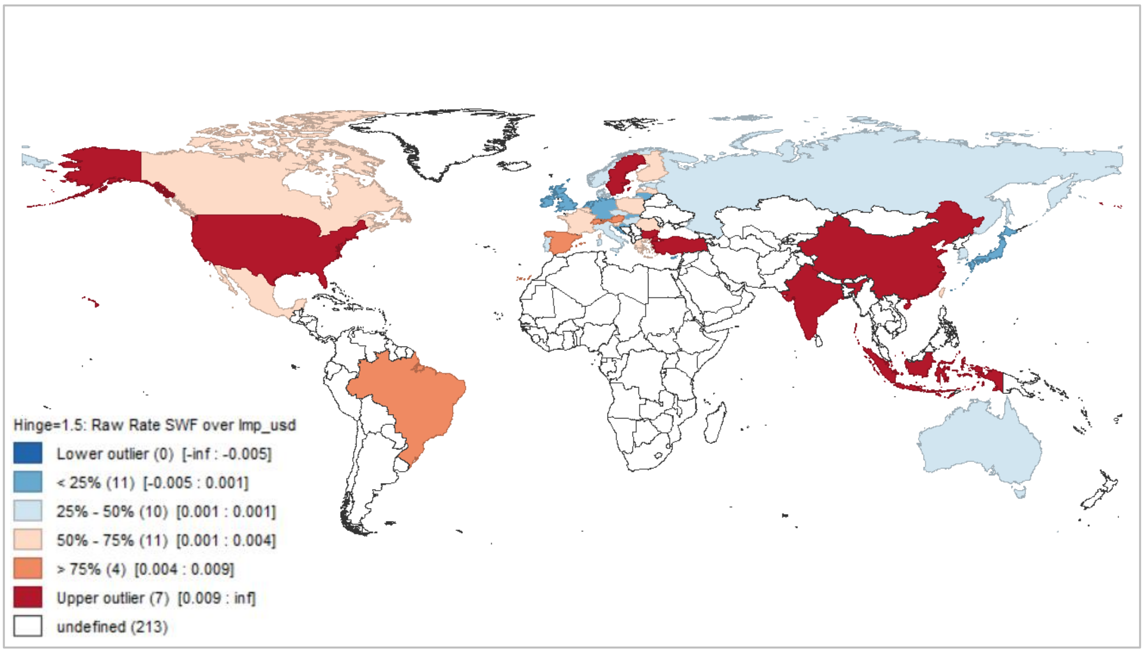
Country Name	WF_bg (Mm^3)	WSI	SWF (Mm^3)
Australia	111.3	0.016	1.8
Austria	203.2	0.558	113.3
Belgium	137.3	0.267	36.6
Bulgaria	243.5	0.907	220.8
Brazil	460.9	0.120	55.1
Canada	484.1	0.035	16.7
Switzerland	356.5	0.390	139.1
China	4,002.1	1.000	4,002.1
Cyprus	1.6	0.066	0.1
Czechia	133.9	0.051	6.8
Germany	615.6	0.089	54.6
Denmark	64.1	0.053	3.4
Spain	938.9	0.196	184.2
Estonia	7.4	0.032	0.2
Finland	26.1	0.180	4.7
France	864.9	0.127	109.7
United Kingdom	54.6	0.022	1.2
Greece	87.4	0.040	3.5
Croatia	108.2	0.014	1.5
Hungary	342.6	0.015	5.3
Indonesia	231.9	0.695	161.3
India	1,186.3	0.996	1,182.0
Ireland	46.3	0.014	0.7
Japan	25.7	0.125	3.2
South Korea	14.8	0.705	10.4
Lithuania	8.1	0.012	0.1
Luxembourg	2.2	0.013	0.0
Latvia	20.1	0.037	0.7
Mexico	62.6	0.135	8.4
Malta	0.7	0.752	0.5
Netherlands	58.3	0.031	1.8
Norway	27.8	0.168	4.7
Poland	484.3	0.098	47.2

Country Name	WF_bg (Mm^3)	WSI	SWF (Mm^3)
Portugal	54.6	0.043	2.3
Romania	457.4	0.062	28.1
Russian Federation	940.2	0.014	12.8
Slovakia	48.1	0.012	0.6
Slovenia	104.9	0.050	5.3
Sweden	110.7	0.698	77.3
Turkey	530.9	0.351	186.6
Taiwan	95.1	0.188	17.9
United States of America	1,093.5	0.464	507.9
Rest of the World	10,485.2	0.637	6,680.8

Source: own elaboration on WIOD data

The geographic distribution of SWF intensity, expressed in water volume per unit of US dollar of direct and indirect imports, is represented also in Figure 15.

Figure 15. Italian Scarse Water Footprint (SWF) intensity by Country of water origin (Cubic meters by US dollar of direct and indirect imports)

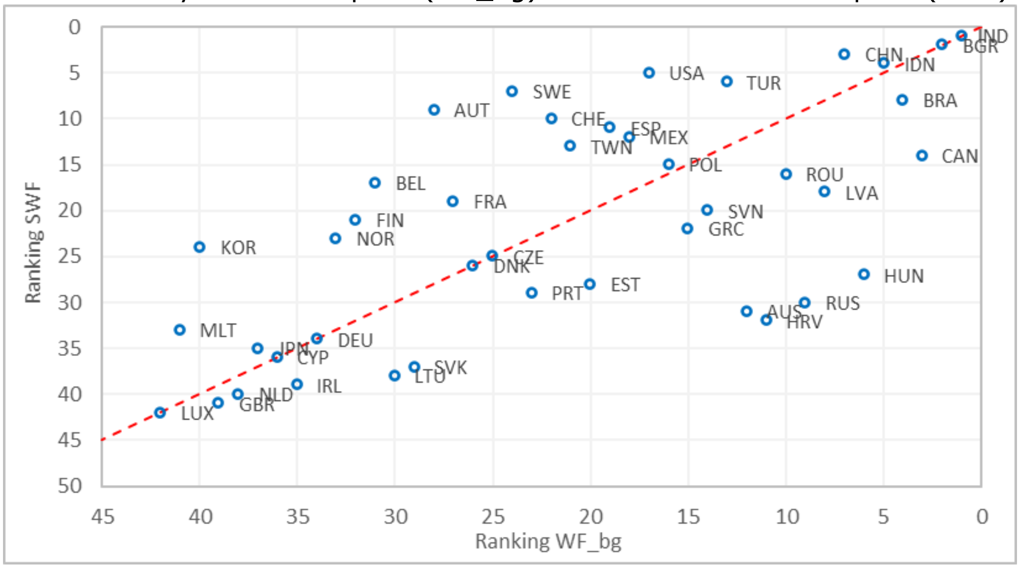


Source: own elaboration on WIOD data

The effect of moving from a simple volumetric measure of WF to a scarcity-based one is represented in Figure 16. The graph compares the ranking of countries associated with the Italian external water footprint, considering the WF and SWF intensities (volume of water divided by the value of direct and indirect imports, in m^3/USD)

The countries above the red dashed line show an increase in the ranking when considering SWF while the countries below the line show a decrease. India is ranked first for both the indicators. Moving from WF to SWF the most notable change in ranking refers to Austria, rising from 28th to 9th place due to its relatively high WSI (0.558), while Russia, a country with abundance in water resources, falls from 9th to 30th place due to its low WSI value (0.014). China rise from 7th to 3rd due to its WSI equal to one.

Figure 16. Ranking of countries with the highest contribution to the Italian Blue and Grey Water Footprint (WF_bg) and Scarce Water Footprint (SWF)



Source: own elaboration on WIOD data

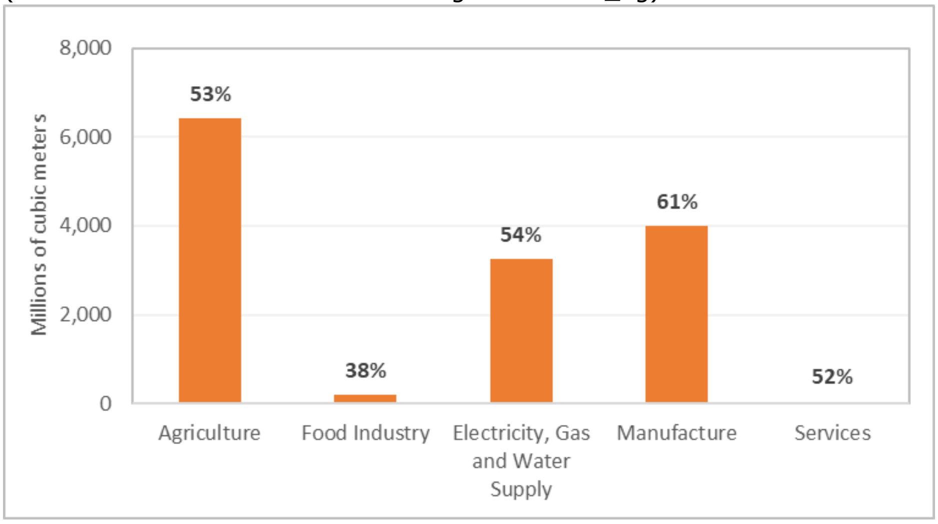
Table 11 and Figure 17 show the industry distribution of external WF_bg and external SWF. The industry where the external SWF represents a larger share of external WF_bg are the Manufacture (61%) while the sector with the least importance of scarce water exploitation is Food Industry (38%).

Table 11. Industry distribution of External WF and External SWF
(Millions of cubic meters, Mm^3)

Economic Sector	WF_bg	SWF	SWF/WF_bg
Agriculture	12,095	6,417	53%
Food Industry	504	189	38%
Electricity, Gas and Water Supply	6,055	3,260	54%
Manufacture	6,606	3,997	61%
Services	75	39	52%
Total	25,334	13,901	55%

Source: own elaboration on WIOD data

Figure 17. Industry distribution of External SWF
(Absolute value in Mm^3 and Percentage of the WF_bg)



Source: own elaboration on WIOD data

Table 12 shows the distribution of SWF considering both industry and geographic origin of imports. The largest contribution to the SWF is generated by Agriculture in the 42 WIOD Countries (3,412 Mm^3) which represents a 46.2% of agricultural WF_bg in this region. For the Electricity, Gas and Water Supply sector, the largest share comes from the Rest of the World (2,176 Mm^3) while for Manufacture the contribution of the 42 countries (mostly industrialized) is two times that of the Rest of the World.

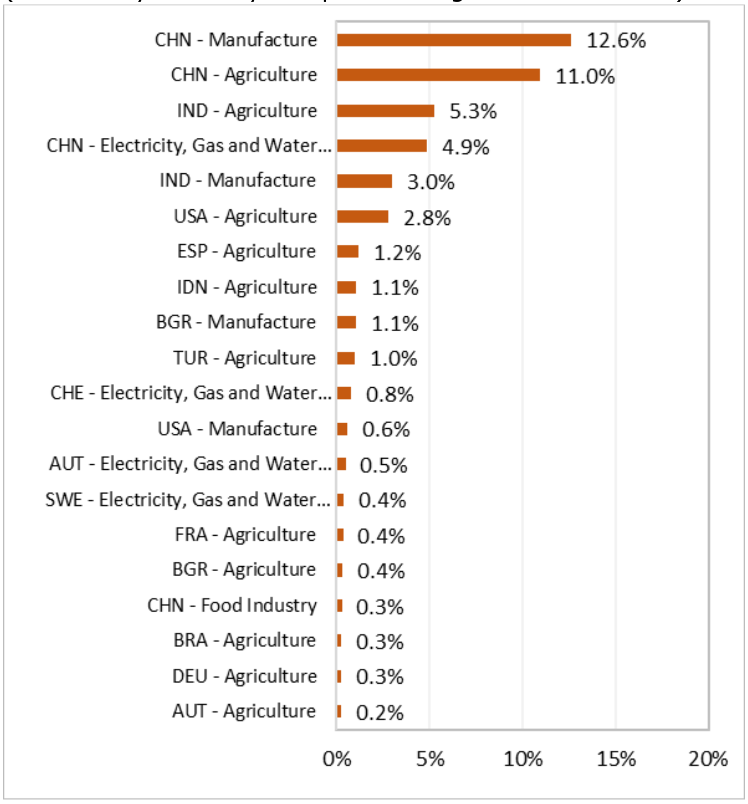
Table 12. SWF Industry distribution by Region

Economic Sector	Italy (Mm^3)	42 WIOD Countries (Mm^3)	Rest of The World (Mm^3)	Total SWF (Mm^3)	% Total
Agriculture	833	3,412	3,005	7,249	43.8%
Food Industry	86	100	89	275	1.7%
Electricity, Gas and Water Supply	1,020	1,084	2,176	4,281	25.9%
Manufacture	128	2,619	1,378	4,124	24.9%
Services	13	6	33	52	0.3%
Households Consumption	555	0	0	555	3.4%
Total	2,634	7,221	6,681	16,536	100.0%
% Total	15.9%	43.7%	40.4%	100.0%	

Source: own elaboration on WIOD data

The graph in
Figure 18 shows the contribution to the Italian external SWF of the first country-industry, accounting for almost the half (48.1%) of the total external SWF. The participation of Manufacture in China and India, Agriculture in China, India and United States of America, and Electricity, Gas and Water Supply in China stand out, these 6 country-economic sector pairs representing 40% of the external SWF of Italian consumption.

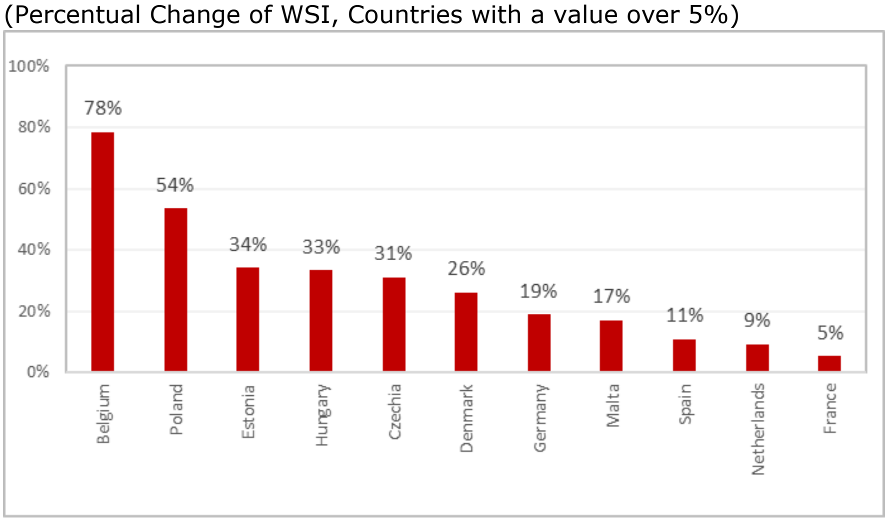
Figure 18. Percentage of Italian External SWF by region-economic sector
(20 Country-Industry hotspot with higher External SWF)



Source: own elaboration on WIOD data

A further result of interest that can be derived is the contribution of Italian consumption to the impact on freshwater ecosystems in other countries. To evaluate this, the WSI of each country (considering blue and grey water external footprint) has been calculated excluding the share of water withdrawals required by Italian imports. The Figure 19 shows the percentage change in WSI in countries for which export to Italy mostly affects the pressures on scarce water resources

Figure 19. Change of WSI due to Italian Consumption Pressure by Country
(Percentual Change of WSI, Countries with a value over 5%)



Source: own elaboration on WIOD data

Belgium, Poland, Estonia and Hungary correspond to the most affected countries, both considering the percentage change in WSI and the initial value of WSI (without Italian consumption). When the initial value is higher the marginal effects of an increase are most important, due to the fact that WSI is a non-linear measure of impacts increasing more than proportionally beyond a given level of the exp0loitation of water resources. Table 13 shows the changes in the countries most affected by Italian consumption.

Table 13. WSI with and without Italian Imports
(Countries with a value of change over 5%)

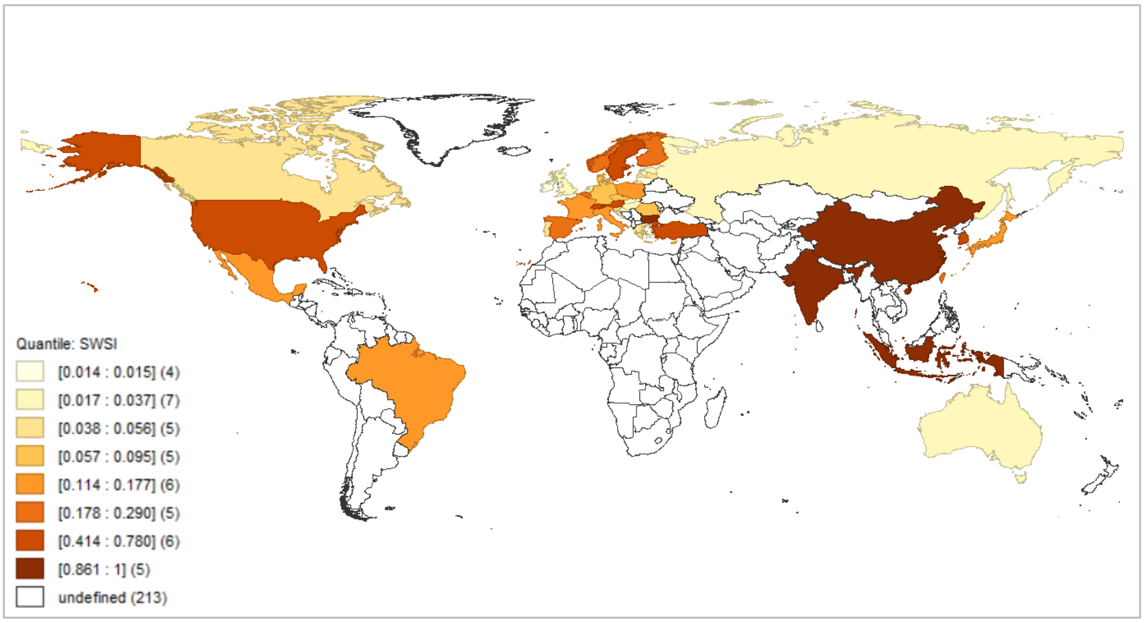
Country Name	WSI without Italian Consumption	WSI	Change in WSI
Belgium	0.149	0.267	78.4%
Poland	0.064	0.098	53.5%
Estonia	0.024	0.032	34.1%
Hungary	0.012	0.015	33.3%
Czechia	0.039	0.051	31.0%
Denmark	0.042	0.053	26.2%
Germany	0.075	0.089	18.9%
Malta	0.642	0.752	17.1%
Spain	0.177	0.196	10.7%
Netherlands	0.028	0.031	9.1%
France	0.120	0.127	5.3%

Source: own elaboration on WIOD data

3.2.3 Social-Scarce Water Footprint

The SoSWF calculation has been carried out combining the Social Water Stress Index (SWSI) based on the Human Development Index (HDI) and the Water Stress Index (WSI). The map in Figure 20 shows the geographic pattern of the stress on water resources when the WSI is adjusted to consider the fulfillment of social goals in each country.

Figure 20. Social Water Stress Index (SWSI) by Country



Source: own elaboration on WIOD data and UNDP data

No significant changes are observed in the ranking of the countries associated with the Italian external water footprint, considering both SWF and SoSWF. The maximum change in the ranking corresponds to an increase of two places (Hungary and Romania) and a decrease of two places (Denmark), which is mainly due to the fact that these countries are relatively worse and better in terms of social goals fulfillments (HDI), respectively.

The total SoSWF for Italy amounts to 21,003 Mm^3, corresponding to 43.1% of the blue and grey volumetric WF, against the 33.9% share obtained without adjusting for social trade-offs. The share relying on domestic water resources (2,987 over 21,003 Mm3) increases to 14,2% (compared to 11.3%) when the social trade-offs are considered. The largest amount of SoSWF is no longer concentrated in the 42 Countries (7,531 Mm3), now showing a higher value in the Rest of The World (10,485 Mm3), due to the higher average water stress and the lower average value of the human development index in the countries included in this region (Table 14).

Table 14. Italy's Social-Scarse Water Footprint (SoSWF) by region
(Millions of cubic meters, Mm^3)

Region	Italy	42 Countries	Rest of the World	Total
WF_bg	23,412	14,848	10,485	48,745
SoSWF	2,987	7,531	10,485	21,003
SoSWF/WF_bg	12.8%	50.7%	100.0%	43.1%

Source: own elaboration on WIOD data

Table 15 presents the water footprint (WF_bg), the social water stress index (SWSI) and the social-scarce water footprint (SoSWF) for the 43 regions (42 WIOD Countries and the Rest of the World) while

Figure 21 provides the geographic variability of SoSWF intensities for the single countries considered.

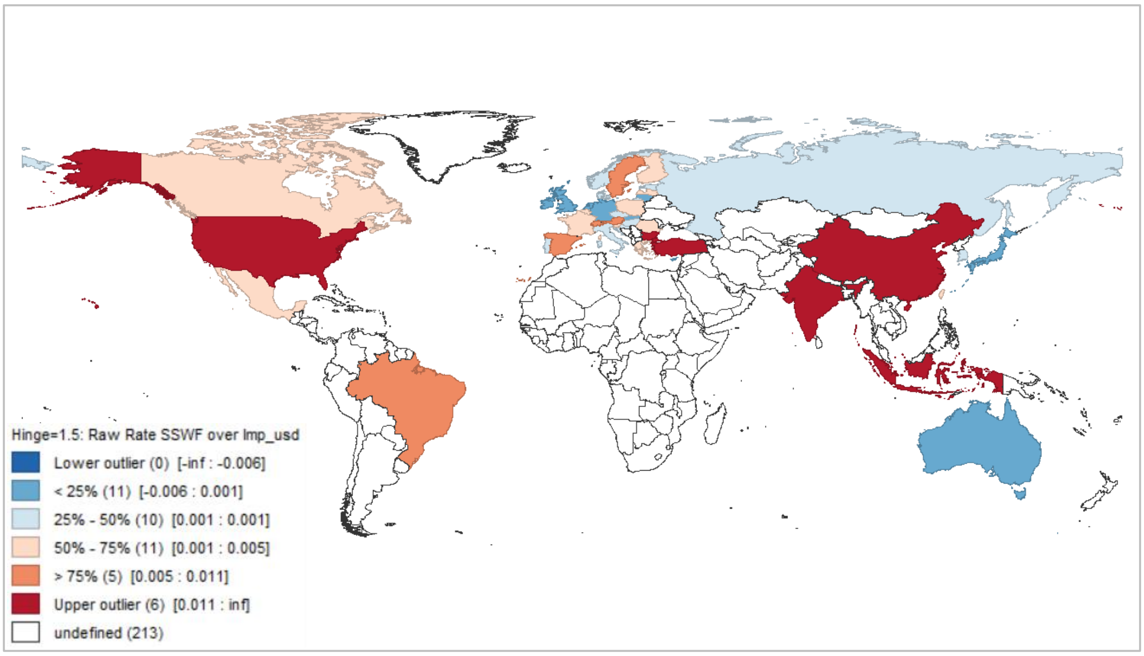
Table 15. Italy's Social-Scarse Water Footprint (SoSWF) by country

Country Name	WF_bg (Mm3)	SWSI	SoSWF (Mm3)
Australia	111.3	0.018	2.0
Austria	203.2	0.611	124.1
Belgium	137.3	0.290	39.9
Bulgaria	243.5	1.000	243.5
Brazil	460.9	0.158	72.9
Canada	484.1	0.038	18.2
Switzerland	356.5	0.414	147.7
China	4002.1	1.000	4002.1
Cyprus	1.6	0.076	0.1
Czechia	133.9	0.057	7.7
Germany	615.6	0.095	58.3
Denmark	64.1	0.057	3.6
Spain	938.9	0.221	207.4
Estonia	7.4	0.037	0.3
Finland	26.1	0.194	5.1

Country Name	WF_bg (Mm3)	SWSI	SoSWF (Mm3)
France	864.9	0.142	122.8
United Kingdom	54.6	0.024	1.3
Greece	87.4	0.045	4.0
Croatia	108.2	0.017	1.8
Hungary	342.6	0.018	6.3
Indonesia	231.9	1.000	231.9
India	1186.3	1.000	1186.3
Ireland	46.3	0.015	0.7
Japan	25.7	0.138	3.6
South Korea	14.8	0.780	11.5
Lithuania	8.1	0.014	0.1
Luxembourg	2.2	0.014	0.0
Latvia	20.1	0.044	0.9
Mexico	62.6	0.177	11.1
Malta	0.7	0.861	0.6
Netherlands	58.3	0.033	1.9
Norway	27.8	0.178	5.0
Poland	484.3	0.114	55.0
Portugal	54.6	0.050	2.8
Romania	457.4	0.076	34.7
Russian Federation	940.2	0.017	15.9
Slovakia	48.1	0.015	0.7
Slovenia	104.9	0.056	5.9
Sweden	110.7	0.747	82.7
Turkey	530.9	0.441	234.4
Taiwan	95.1	0.257	24.5
United States of America	1093.5	0.505	552.0
Rest of the World	10485.2	1.000	10485.2

Source: own elaboration on WIOD data

Figure 21. Italian Social-Scarse External Water Footprint (SoSWF) intensity by Country of water origin
(Cubic meters by US dollar of direct and indirect imports)



Source: own elaboration on WIOD data

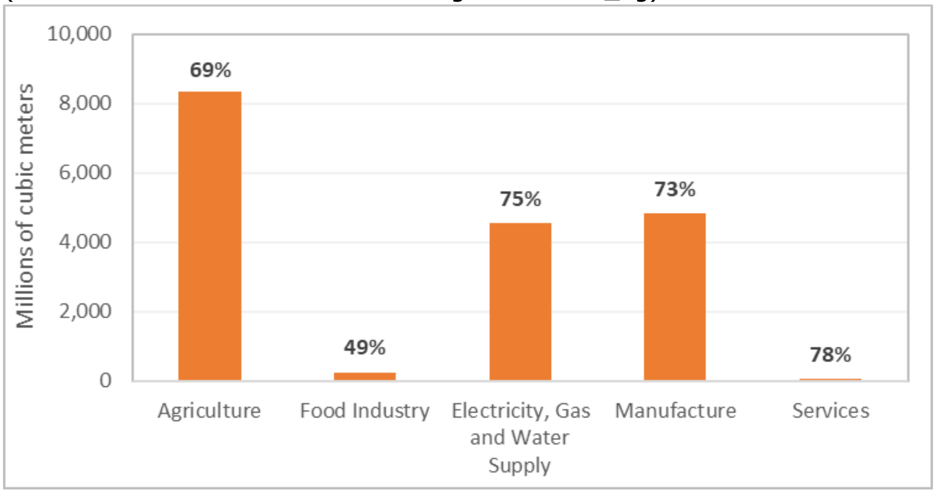
Table 16 and Figure 22 show the industry distribution of external SoSWF and its comparison with external WF_bg. The sectors where external SoSWF is more relevant within total WF are Services (78%) while the sector with the least importance is Food Industry (49%).

Table 16. Sectoral distribution of external WF and SWF
(Millions of cubic meters, Mm^3)

Economic Sector	WF_bg	SoSWF	SoSWF/WF_bg
Agriculture	12,095	8,329	69%
Food Industry	504	247	49%
Electricity, Gas and Water Supply	6,055	4,543	75%
Manufacture	6,606	4,839	73%
Services	75	58	78%
Total	25,334	18,016	71%

Source: own elaboration on WIOD data

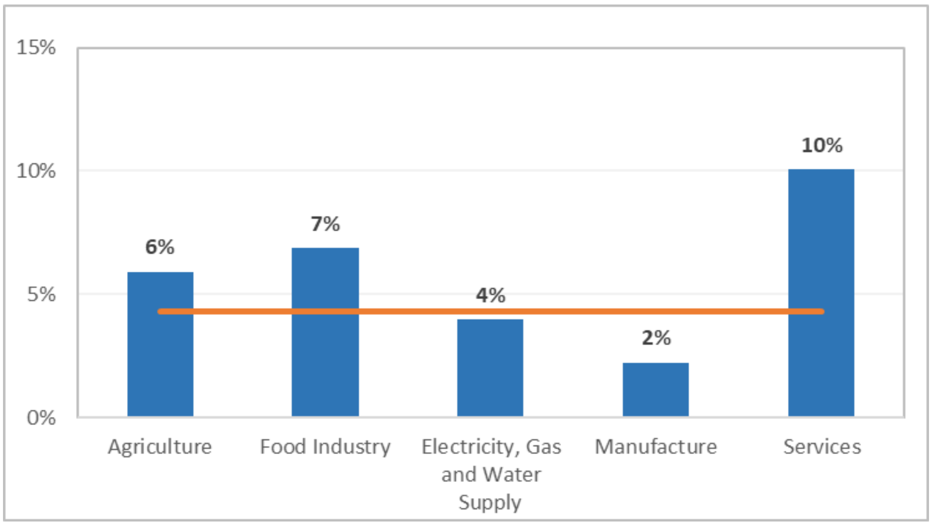
Figure 22. Sectoral distribution of external WF and SoSWF
(Absolute value in Mm^3 and Percentage of the WF_bg)



Source: own elaboration on WIOD data

Figure 23 shows the percentage difference between external SoSWF and SWF of Italy across the five macro-sectors of the economy. The increase on average is 4.3%, however, there is a sectoral variability. The percentage difference for Agriculture, Food Industry and Services is above average, i.e., on average the water coming from these imports comes from countries with a lower HDI compared to imports from Electricity-Gas-Water and Manufacture. It is important to note that given the use of the MRIO methodology, the contribution of different industries to Italy's external water footprint (scarse and social-scarse) corresponds to the whole value chain, not only to those industries/countries from which Italy imports directly, which makes the interpretation less intuitive (the same applies to Manufacture).

Figure 23. Percentage difference between sectoral SoSWF and SWF for the 42 Countries of WIOD



Source: own elaboration on WIOD data

The increase in the scarcity weighted indicator of water footprint due to the consideration of social trade-offs in different industries depends on the geographic composition of imports. Table 17 shows the breakdown of the social-scarse water footprint by origin of imports. The largest contribution to the SoSWF is generated by imports from the Rest of the World (4,716 Mm^3), now exceeding Agriculture in the 42 WIOD countries (3,614 Mm^3) different from the SWF case, due to the lower level of human development in the countries included in the ROW group. Also, for the Electricity, Gas and Water Supply sector, the largest share comes from the Rest of the World (3,416 Mm^3). In the case of Manufacture, the contribution of the 42 countries for which disaggregated accounts are available (mostly industrialized) is still higher than the Rest of the World (as in the SFW case).

Table 17. SoSWF sectoral distribution by regions

Economic Sector	Italy (Mm^3)	42 Countries (Mm^3)	Rest of The World (Mm^3)	Total SWF (Mm^3)	% Total
Agriculture	944	3,614	4,716	9,274	44.2%
Food Industry	97	106	140	344	1.6%
Electricity, Gas and Water Supply	1,157	1,127	3,416	5,699	27.1%
Manufacture	145	2,677	2,162	4,984	23.7%
Services	15	7	51	73	0.3%
Households Consumption	629	0	0	629	3.0%
Total	2,987	7,531	10,485	21,003	100.0%
% Total	14.2%	35.9%	49.9%	100.0%	

Source: own elaboration on WIOD data

4 Discussion and Conclusions

The aim of this paper was to provide an in-depth analysis of water footprint generated by Italian consumption. The study of the Italian case was also an opportunity to review the debate on the WF concept, comparing alternative approaches to its quantification that have been proposed in the last two decades.

The analysis was based on the World Input Output Database (WIOD), a multiregional input-output table of the world economy with a satellite account of water resource use. This information allowed to quantify the total WF of Italian consumption, considering both domestic and foreign demand and taking into account the structure of the global value chain in quantifying (direct and indirect) virtual water flows associated with Italian imports.

The production of goods and services consumed in Italy in 2014 required the use of 136,543 Mm^3 of water. This amount was composed for the largest part (about 64.3%) of water from precipitation and soil moisture (green water), while renewable groundwater and surface water sources (blue water) provided about the 20% (26,670 Mm^3, 19.5%) of total requirements. The exploitation of blue water generated an additional requirement of 22,076 Mm^3 (16.2%) to restore the quality of freshwater renewable sources (grey water).

When considering only renewable resources of water (blue and grey) about the half of Italy's WF exerted its pressures on water resources of other countries, through imports for the largest part from Agriculture (24.8%) Manufacture (13.5%) and Electricity, Gas and Water Supply (12.4%) sectors. The three top countries exporting virtual blue and grey water to Italy were China (15.8%), India (4.6%) and USA (4.3%). However, when looking to the *intensity* of virtual water imports (Mm^3 per import $) the top countries included, together with China and India, also Canada, Brazil and Indonesia.

The volumetric measure of WF depicts the contribution of Italy to the exploitation of global water resources but hardly allows to evaluate the impacts generated on water resources and the environment. The effective pressure on water resources has been measured as an impact-weighted water volume, considering an indicator of stress on water resources of a given country. The logic of the *scarse* WF consists of assigning a positive value only to water that is used in a context of adverse environmental impacts. Overall, SWF accounts for 33.9% of volumetric WF but the breakdown by geographic area highlights a relevant asymmetry between domestic and external water exploitation: while only 11.2% of domestic WF generated adverse impacts, SWF for imports amounted to 54.9% of water resources used for producing imported goods. A relevant part of impacts generated by Italian consumption were *exported* to other countries. The SWF was directed to few main countries: about 45% of these impacts were generated by Manufacture, Agriculture and Electricity, Gas and Water Supply in China and India.

A further qualification of Italian WF was obtained considering the Social-Scarce Water Footprint (SoSWF). In broad terms this indicator assigns a different impact to water used in regions with the same level of scarcity/impact on their water resources if they have different degrees of fulfillment of social goals. A country with a higher level of human development has better opportunities to improve the management of its water resources (infrastructures and human capital) and to reduce the negative social consequences of water scarcity. About 43% of WF generated impacts on environmentally *and* socially scarce water resources, deepening the asymmetries between domestic and external footprint (12.8% vs. 71.1% of WF). The highest pressures of Italian imports were directed to water resources in countries belonging to the Rest of the World group of the WIOD database, including several developing countries.

Beside the comprehensive and detailed analysis of Italy's WF, this study yielded results also on the methodological side. The Italy case study was used to carry out a systematic comparison between the Water Embodied in Bilateral Trade (WEBT) and the Multi Regional Input Output (MRIO) approaches to quantification of WF. Despite the conceptual higher precision of the MRIO approach, at the aggregate level the two methods lead to very similar results for the domestic footprint (the largest difference occurring for the Manufacture estimates). Larger differences emerged in the external (aggregated) WF, especially for imports from Manufacture (11.1%) and Services (12.3%). The choice of WEBT or MRIO depends on the objective of the study. When the main interest is in bilateral flows between partner countries WEBT it is advisable to use but when the aim of the study is a complete analysis of virtual water flows across the global value chain the MRIO approach should be preferred.

A further methodological achievement of the study refers to the use of an improved indicator of water exploitation, the Water Requirement Index (WRI), to support scarcity-based measures of WF. Different from previous studies we also considered the requirements of grey water. This modification is coherent with the use of the WF as an indicator of impacts, introducing an interesting way to take into account impacts on water *quality*. This led also to relevant changes in the estimated values of SWF by single country.

The results suggest interesting policy implications. Italian consumption generates relevant impacts on water resources mainly in third countries while, at least in aggregate terms, impacts generated in Italy remains below a critical threshold. Furthermore, the adverse effects of Italy's WF is concentrated in countries with a high level of stress on water resources (mainly China and India) and with a relatively lower achievement of social goals (developing countries). Their competitiveness in international trade seems at least partially based on a non-sustainable use of water resources. This is a typical case of market failure.

While the discussion on what policy measures should be designed to address such a problem is beyond the scope of this study, our results suggest the need for an increase and an improvement of information available for the analysis of this issue at the global level. Moreover, to design effective policies, more flexible and improved methods for the assessment of water stress should be used, as the average figures at the country level often hide large regional differences. The marginal change in the stress on water resources generated by the increase of production (both to support domestic and foreign demand) heavily depends on the nature and the distribution of water resources within the country, as well as on their matching with the geographic pattern of the productive system. The latter is driven by social and economic more than ecological factors. The use of the same logistic function to calculate a WSI based on a national average indicator of exploitation on water resources, is likely to yield a significant bias in the estimation in the case of large economies such as China, USA or India.

The last remark represents also the first main limitation of the study that is worth to stress here. The choice to use an average index of water exploitation to produce a scarcity (or socially) weighted measure of water stress for all production activities in a given country was driven by data availability. A further limitation refers to the country disaggregation of the analysis. The use of WIOD database left a high number of countries grouped in the Rest of the World region. This mainly affected results for SoSWF, where critical situations would be likely to emerge when more disaggregated data were available. A matching between different global databases could support a possible improvement of results of the study.

A final consideration on future research perspectives suggested by this study refers to a possible move towards economic assessment and evaluation of WF. Both the volumetric and the scarcity/socially adjusted measures are expressed in physical terms. However, all the more when the estimation is developed within an input-output framework (as in this study), the transformation into monetary values is a fairly natural development of the analysis. Environmentally extended input-output models can be easily used to estimate an opportunity cost-based value of water. Furthermore, the accounting framework can be integrated with satellite accounts for ecosystem services produced by water resources, as the version of the System of Environmental-Economic Accounting for Ecosystem Accounting (United Nations et al., 2021) recently released by UN and other international bodies suggests. This could potentially transform scarcity-weighted measures of WF into the first step of a full economic assessment of impacts on water resources for policy analysis at the national and the global level.

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APPENDICES

Appendix 1

To better illustrate the calculation of WF with the MRIO approach, a scheme with *M=3* is proposed below, which is easily replicable for *M>3*, as proposed by Arto et al. (2016). Italy (or the interest region/country) it represented by the region 1.

Equation (18) for three regions (*M=3*) and *N* sectors can be written as follows:

$$\begin{bmatrix} W_E^1 \\ W_E^2 \\ W_E^3 \end{bmatrix} = \begin{bmatrix} \hat{v}^1 & 0 & 0 \\ 0 & \hat{v}^2 & 0 \\ 0 & 0 & \hat{v}^3 \end{bmatrix} \begin{bmatrix} L^{11} & L^{12} & L^{13} \\ L^{21} & L^{22} & L^{23} \\ L^{31} & L^{32} & L^{33} \end{bmatrix} \begin{bmatrix} y^{11} + y^{12} + y^{13} \\ y^{21} + y^{22} + y^{23} \\ y^{31} + y^{32} + y^{33} \end{bmatrix} \quad (1.1)$$

Where the (*nx1*) vector W_E^1 represents the total direct water used (production-based approach) in the region 1, without considering households direct use, by economic sector.

To obtain the domestic water (*nx1*) vector (W_{Dom}^1) and the (*nx1*) vectors of virtual water imports associated to the consumption in region 1 it is imposed $y^{i2} = y^{i3} = 0$. That is, only the domestic and external water associated to the final consumption in region 1 is considered.

$$\begin{bmatrix} W_{Dom}^1 \\ W_{Imp}^{12} \\ W_{Imp}^{13} \end{bmatrix} = \begin{bmatrix} \hat{v}^1 & 0 & 0 \\ 0 & \hat{v}^2 & 0 \\ 0 & 0 & \hat{v}^3 \end{bmatrix} \begin{bmatrix} L^{11} & L^{12} & L^{13} \\ L^{21} & L^{22} & L^{23} \\ L^{31} & L^{32} & L^{33} \end{bmatrix} \begin{bmatrix} y^{11} \\ y^{21} \\ y^{31} \end{bmatrix} \quad (1.2)$$

Solving equation (1.2) we get:

$$W_{Dom}^1 = \hat{v}^1 (L^{11} y^{11} + L^{12} y^{21} + L^{13} y^{31}) \quad (1.3)$$

$$W_{Imp}^{12} = \hat{v}^2 (L^{21} y^{11} + L^{22} y^{21} + L^{23} y^{31}) \quad (1.4)$$

$$W_{Imp}^{13} = \hat{v}^3 (L^{31} y^{11} + L^{32} y^{21} + L^{33} y^{31}) \quad (1.5)$$

The total virtual water imports for domestic consumption (external water footprint) can be expressed as the sum of water imports of region 1 from region 2 (W_{Imp}^{12}) and from region 3 (W_{Imp}^{13}):

$$W_{Imp}^1 = W_{Imp}^{12} + W_{Imp}^{13} \quad (1.6)$$

The terms $\hat{v}^1 L^{12} y^{21}$ and $\hat{v}^1 L^{13} y^{31}$ in equation (1.3) correspond to the feedback effect (Moran, 2017), that is, water exports from region 1 that then return to region 1 from regions 2 and 3. In this work this water is associated with domestic production. To avoid double counting these terms are not considered in exports.

The total water footprint (consumption-based) is obtained using equations (1.3) and (1.6):

$$WF_{Cba}^1 = (W_{Dom}^1)'i + (W_{Imp}^1)'i + W_{hh}^1 \tag{1.7}$$

To obtain the water exports (nx1) vector (W_{Exp}^1) from region 1 to regions 2 and 3, it is imposed $\hat{v}^2 = \hat{v}^3 = 0$ and $y^{11} = y^{21} = y^{31} = 0$. That is, water exports refers to water from region 1 that goes to other countries and does not return to region 1.

$$\begin{bmatrix} W_{Exp}^1 \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} \hat{v}^1 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} L^{11} & L^{12} & L^{13} \\ L^{21} & L^{22} & L^{23} \\ L^{31} & L^{32} & L^{33} \end{bmatrix} \begin{bmatrix} y^{12} + y^{13} \\ y^{22} + y^{23} \\ y^{32} + y^{33} \end{bmatrix} \tag{1.8}$$

Solving equation (30) we get:

$$W_{Exp}^1 = \hat{v}^1 [L^{11} (y^{12} + y^{13}) + L^{12} (y^{22} + y^{23}) + L^{13} (y^{32} + y^{33})] \tag{1.9}$$

Unlike Arto et al. (2016), terms associated with the feedback effect (see above) are not considered to avoid double counting in the production-based water footprint.

The direct use of water (production-based approach) is obtained using equations (1.3) and (1.9):

$$DW_{Pba}^1 = (W_{Dom}^1)'i + (W_{Exp}^1)'i + W_{hh}^1 \tag{1.10}$$

Total virtual water imports correspond to water contained in goods for final consumption in region 1 and water contained in products exported from region 1 to the other regions, the latter are known as re-exports. To obtain the re-exports (nx1) vectors ($W_{Re\_Exp}^{12}$, $W_{Re\_Exp}^{13}$) it is imposed $y^{11} = 0$ and $y^{2i} = y^{3i} = 0$, $\forall i$.

$$\begin{bmatrix} 0 \\ W_{Re-Exp}^{12} \\ W_{Re\_Exp}^{13} \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 \\ 0 & \hat{v}^2 & 0 \\ 0 & 0 & \hat{v}^3 \end{bmatrix} \begin{bmatrix} L^{11} & L^{12} & L^{13} \\ L^{21} & L^{22} & L^{23} \\ L^{31} & L^{32} & L^{33} \end{bmatrix} \begin{bmatrix} y^{12} + y^{13} \\ 0 \\ 0 \end{bmatrix} \quad (1.11)$$

Solving equation (1.11):

$$W_{Re\_Exp}^{12} = \hat{v}^2 L^{21}(y^{12} + y^{13}) \quad (1.12)$$

$$W_{Re\_Exp}^{13} = \hat{v}^3 L^{31}(y^{12} + y^{13}) \quad (1.13)$$

Finally, the total imports (nx1) vector in region 1 (by economic sectors) can be obtained by equations (1.6), (1.12) and (1.13):

$$W_{Tot\_Imp}^{1} = W_{Imp}^{12} + W_{Imp}^{13} + W_{Re\_Exp}^{12} + W_{Re\_Exp}^{12} \quad (1.14)$$

The study by White et al. (2015) calculates the WF and SWF for the Haihe River Basin in China, considering the MRIO approach; this study is taken as a reference. As explained in the introduction, blue water and grey water are used to calculate SWF and SoSWF.

Following the previous methodology and considering equations (1.2-1.6), by incorporating the water stress indicator (WSI) of each country, it is possible to calculate the domestic economic scarse water (nx1) vectors (SW_{Imp}^{12}, SW_{Imp}^{13}) and the components of the external scarse water footprint (nx1) vector (SW_{Imp}^{1}).

$$SW_{Dom}^{1} = WSI_1 \cdot \hat{v}^1(L^{11}y^{11} + L^{12}y^{21} + L^{13}y^{31}) \quad (1.15)$$

$$SW_{Imp}^{12} = WSI_2 \cdot \hat{v}^2(L^{21}y^{11} + L^{22}y^{21} + L^{23}y^{31}) \quad (1.16)$$

$$SW_{Imp}^{13} = WSI_3 \cdot \hat{v}^3(L^{31}y^{11} + L^{32}y^{21} + L^{33}y^{31}) \quad (1.17)$$

It is also calculated the scarse consumption of households in Italy and the external scarse water footprint (nx1) vector (SW_{Dom}^{1}) to obtain the total scarse water footprint (SWF_{Cba}^{1}).

$$SW_{hh}^{1} = WSI_1 \cdot W_{hh}^{1} \quad (1.18)$$

$$SW_{Imp}^{1} = SW_{Imp}^{12} + SW_{Imp}^{13} \tag{1.19}$$

$$SWF_{Cba}^{1} = (SW_{Dom}^{1})'i + (SW_{Imp}^{1})'i + SW_{hh}^{1} \tag{1.20}$$

In the same way, by incorporating the social water stress indicator (SWSI) of each country, it is possible to calculate the domestic economic social-scarse water (nx1) vectors ($SoSW_{Imp}^{12}$, $SoSW_{Imp}^{13}$) and the components of the external scarse water footprint (nx1) vector ($SoSW_{Imp}^{1}$).

Appendix 2

Table 2.1, Table 2.2 and Table 2.3 presents the results of the blue, green and gray water footprint by industry, calculated using the MRIO methodology. The results are disaggregated by region (Italy, 42 Countries and the Rest of the World).

Out of a total of 56 industries, 16 directly withdraw water from surface and groundwater sources (blue water), 3 capture directly water from rainfall and soil moisture (green water) and 13 presents water requirements to dilute the pollutants associated with their direct discharges into surface and groundwater sources (grey water).

Table 2.1. Italian Water Footprint by Industry (Blue Water)
(Millions of cubic meters)

Industry	Macro Sector	MRIO Blue Water			
		Italy	42 Countries	Rest of the World	Total
Crop and animal production, hunting and related service activities	Agriculture	3,167.0	2,604.4	3,019.4	8,790.7
Forestry and logging	Agriculture	103.0	127.3	193.2	423.5
Fishing and aquaculture	Agriculture	111.4	191.0	213.9	516.2
Manufacture of food products, beverages and tobacco products	Food Industry	110.5	51.4	8.8	170.7
Manufacture of textiles, wearing apparel and leather products	Manufacture	43.9	61.2	39.7	144.7
Manufacture of paper and paper products	Manufacture	23.9	34.5	5.2	63.7
Printing and reproduction of recorded media	Manufacture	16.9	8.2	1.6	26.7
Manufacture of coke and refined petroleum products	Manufacture	0.0	0.0	0.0	0.0
Manufacture of chemicals and chemical products	Manufacture	27.0	188.4	39.0	254.4
Manufacture of basic pharmaceutical products and pharmaceutical preparations	Manufacture	7.7	71.6	2.7	82.0
Manufacture of other non-metallic mineral products	Manufacture	24.5	15.5	3.0	43.0
Manufacture of basic metals	Manufacture	6.6	72.3	26.1	104.9
Manufacture of fabricated metal products, except machinery and equipment	Manufacture	14.2	35.4	5.6	55.3

Industry	Macro Sector	MRIO Blue Water			
		Italy	42 Countries	Rest of the World	Total
Electricity, gas, steam and air conditioning supply	Electricity, Gas and Water Supply	1,532.3	1,498.5	1,697.5	4,728.3
Water collection, treatment and supply	Electricity, Gas and Water Supply	7,536.2	1,140.6	1,718.1	10,395.0
Publishing activities	Services	16.5	4.1	3.1	23.7

Source: own elaboration

Table 2.2. Italian Water Footprint by Industry (Green Water) (Millions of cubic meters)

Industry	Macro Sector	MRIO Green Water			
		Italy	42 Countries	Rest of the World	Total
Crop and animal production, hunting and related service activities	Agriculture	29,634.1	27,984.6	22,049.0	79,667.8
Forestry and logging	Agriculture	963.7	1,671.8	1,410.9	4,046.4
Fishing and aquaculture	Agriculture	1,042.4	1,479.0	1,561.8	4,083.1

Source: own elaboration

Table 2.3. Italian Water Footprint by Industry (Grey Water) (Millions of cubic meters)

Industry	Macro Sector	MRIO Grey Water			
		Italy	42 Countries	Rest of the World	Total
Crop and animal production, hunting and related service activities	Agriculture	3,765.0	3,909.3	1,136.2	8,810.5
Forestry and logging	Agriculture	122.4	309.1	72.7	504.3
Fishing and aquaculture	Agriculture	132.4	237.8	80.5	450.7
Manufacture of food products, beverages and tobacco products	Food Industry	650.6	311.9	131.5	1,094.0
Manufacture of textiles, wearing apparel and leather products	Manufacture	258.5	581.4	647.6	1,487.5
Manufacture of paper and paper products	Manufacture	140.9	326.1	82.1	549.1
Printing and reproduction of recorded media	Manufacture	99.5	76.8	25.8	202.1
Manufacture of chemicals and chemical products	Manufacture	159.2	1,440.6	627.4	2,227.2
Manufacture of basic pharmaceutical products and pharmaceutical preparations	Manufacture	45.4	283.7	43.5	372.5
Manufacture of other non-metallic mineral products	Manufacture	144.1	134.5	49.3	327.9
Manufacture of basic metals	Manufacture	38.6	796.5	463.5	1,298.6
Manufacture of fabricated metal products, except machinery and equipment	Manufacture	83.9	317.0	100.2	501.0
Publishing activities	Services	97.4	19.5	48.1	165.0

Source: own elaboration